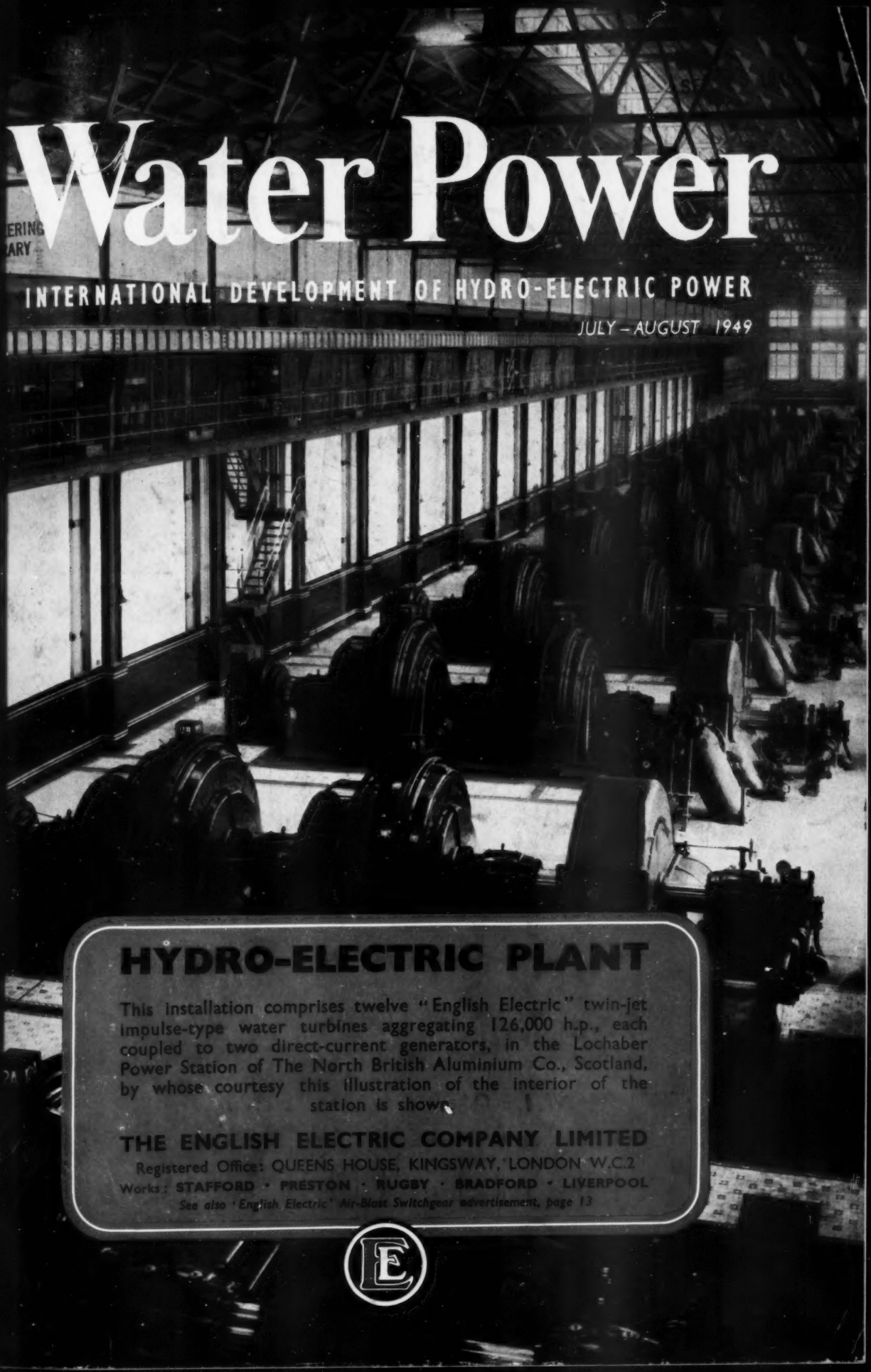
# Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

JULY – AUGUST 1949




**HYDRO-ELECTRIC PLANT**

This installation comprises twelve "English Electric" twin-jet impulse-type water turbines aggregating 126,000 h.p., each coupled to two direct-current generators, in the Lochaber Power Station of The North British Aluminium Co., Scotland, by whose courtesy this illustration of the interior of the station is shown.

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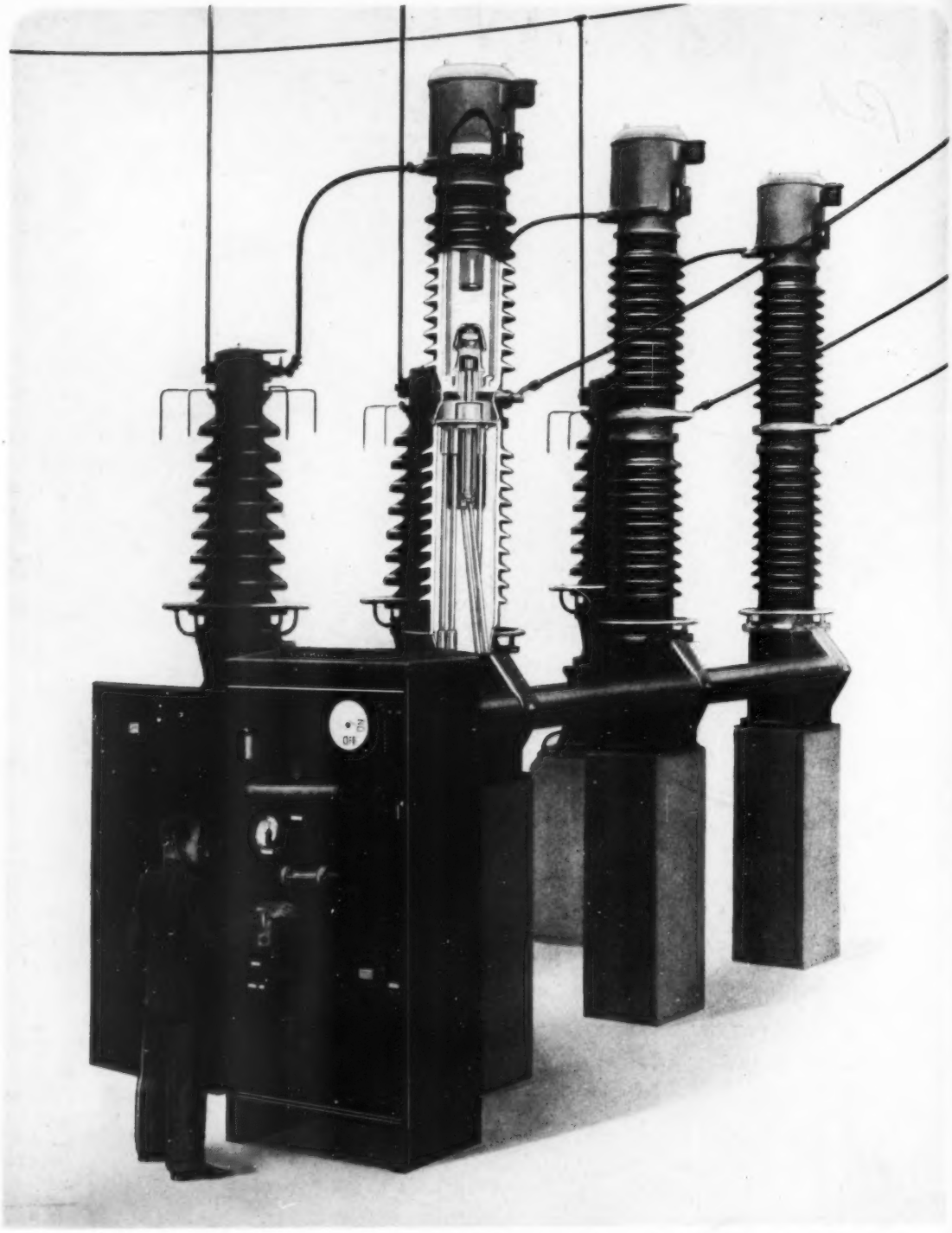
*See also 'English Electric' Air-Blast Switchgear advertisement, page 13*



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# WATER POWER

*A technical journal devoted to the study of all aspects of Hydro-electric developments*

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**CONTENTS FOR JULY—AUGUST 1949**

Leading Article: Bold Measures . . . . . 135
Editorial Notes . . . . . 136
Design of Buildings . . . . . 139
*by J. Eversdon Henderson, A.R.I.B.A.*
Génissiat . . . . . 147
*by R. H. E. Ryley, A.M.I.E.E.*
Choice of Literature . . . . . 151
*by S. P. Hutton, M.Eng., A.M.I.C.E.*
Scottish Hydro-Electric Scheme: Annual report . . . 154
Sir Edward MacColl . . . . . 154
Scottish Projects Inspected . . . . . 155
Pictorial Progress Report . . . . . 156
Power Development in North Canada . . . . . 162
*by E. W. Humphrys*
Progress in Ontario . . . . . 168
Tunnelling Practice . . . . . 172
B.T.H. Works Visited . . . . . 177
Mechanical Engineering Laboratory . . . . . 178
Obituary: John Aiton Kay . . . . . 178
Uganda's Resources . . . . . 179
British Power Conference . . . . . 179
Contractors' Notes . . . . . 180

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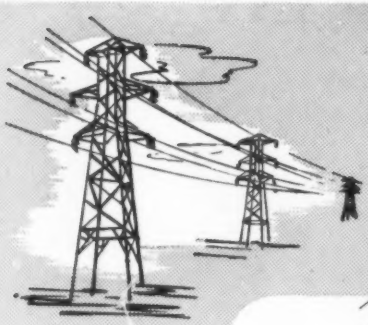

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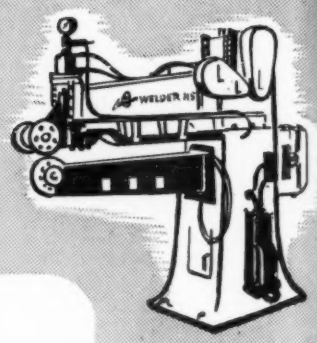

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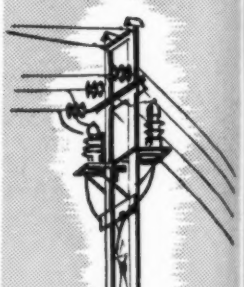

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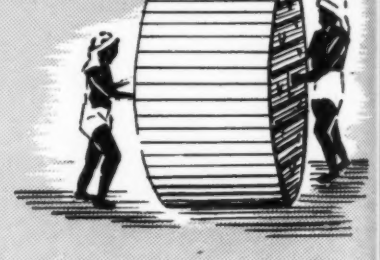


# WATER POWER

*A technical journal devoted to the study of all aspects of Hydro-Electric Development*


## Bold Measures

IN the relatively brief period since plans were first made for the start of this publication and the widespread acceptance of it to-day as a valuable and authoritative source of information, we are well aware of a quickening interest in the development of the world's hydro-electric resources. This resurgence of water power as a prime mover was, of course, inevitable in a post-war period of reconstruction and rehabilitation.

Never before were so many development schemes in prospect: some of them are of unexampled magnificence in conception. They are designed to meet to-day's great need for cheap and abundant power. Upon it depends the economic strength of every country, and those with potential water power, readily available, are fortunate indeed.

In Great Britain the post-war plan to harness the latent energy in the lochs of Scotland is making splendid progress: it has the advantage of being engineered by men of world-wide distinction. Their practical experience was mostly gained in the distant places; but the training of those specialist engineers, and many others of merit, was taken in the universities, the technical institutions—and in the factories of this country, where hydro-electric machinery is made.

So great now is the volume of work in hand and in prospect to help satisfy the world power shortage that further co-ordination of effort is desirable; and to that end the British Electrical and Allied Manufacturers' Association has most recently announced the setting up of a special section to handle the various aspects of hydro-electric machinery production for home and oversea markets.

The appreciation of the immediate need is important; but other moves have also been made in order to maintain the high status of this country in professional teaching and in the practice of hydro-electric techniques in the years to come.

In 1947 the British Hydromechanics Research Association was formed to help expand the knowledge of scientific principles in relation to the manufacture and use of hydraulic machinery and equipment, and to promote and extend research and instruction in such subjects at the universities and technical colleges. The Rt. Hon. Sir John Anderson, its president, said then that "industrialists and Government advisers have realised that British facilities for research and development in fluid mechanics are inadequate for the maintenance of a leading position in the manufacture and efficient utilisation of hydraulic machinery"; and he pledged the co-operation of the Department of Scientific and Industrial Research. He also said that research of this kind would help to alleviate the international shortages of mechanical power, and would enable our national creative talent to be freely developed to the best advantage.

More recently the D.S.I.R. has announced plans for a mechanical engineering research establishment which will devote part of its time to the careful design of hydraulic machinery. This is of particular importance because Great Britain until now has lacked those facilities for research that are available in the United States and Switzerland.

Individual firms are showing foresight as well and one of the principal manufacturers concerned with the production of water power plant in this country has decided that it must take long term steps to augment the ranks of trained engineers. It has established six bursaries at the City and Guilds Institute, and arranged for experienced members of its staff to take an active part in the lectures given at the college. Further, the company decided to construct six model water turbines for presentation to universities so that practical training could be given to students in hydraulic research.

Together, these bold measures are evidence of the Government's intention, supported enthusiastically by manufacturers—collectively, through B.E.A.M.A., and individually—to help industry to help itself.

It promises well for the British manufacturers of hydro-electric equipment.

The response given to the inauguration of this journal in the form of letters welcoming its inception, which have come from very many parts of the world as well as from responsible engineers and officials in this country, strengthens our view that the control of water for the generation of electricity must be one of the greatest aims of mankind in the future. The

ever increasing population of the world demands more food, which requires vast and drastic changes in the methods whereby it is grown, harvested, and transported. The needs of industry are also vital. Only by using more and more power can they be achieved; and only by the utilization of water power resources and the transmission of electricity over vast distances can we hope to provide this power economically where it is most needed.

## Water Power and National Wealth

SOME indication of the importance attached to Great Britain's water power developments in a period of intense international competition for markets was given by the Prime Minister (Mr. C. R. Attlee) when he addressed the British Electrical Power Convention at Torquay recently. Stressing that the nation had still a long way to go before production would meet demand, and the need for replacing obsolete plant the Premier continued: "I look with confidence to managers, technicians and workers in the industry to do their utmost to increase production, so that we can not only meet our home needs, but increase the volume of our exports." Of the great hydro-electric schemes now shaping, Mr. Attlee remarked that he had regular progress reports laid before him, and added significantly: "Here is an outstanding instance in which we shall, by harnessing the water power of this island, make a great increase in the national wealth."

## United States help for Australia

IT is probable that American assistance will be provided for the work on the Snowy River hydro-electric scheme, which was described in our last issue. The United States in the fields of economics and defence has a special interest in Australia, and it is therefore not surprising to learn that President Truman has indicated to the Federal Government in Canberra that every form of assistance possible will be forthcoming from his country. The Australian Federal Minister for Works, Mr. Lemmon, has supplemented the news from the United States in his announcement that highly qualified experts from America will be available to advise the Government on many of the problems involved, both in the initial stages of the project and in its later development. So far the chairman of the Snowy Mountains Commission has not been appointed, but one of the first tasks on taking up his post will be to go to the United States for talks with the experts.

## Tasmania prepares for the Future

TASMANIA, considered to have greater hydro-electric resources than any other Australian state, has taken advantage of the situation to develop big power undertakings, and as a corollary to establish several large industries that otherwise would have been unable to carry out operations in the island. Thus plans have to be made for the future, for only a small part of available water power has yet been utilised. Latest messages show that progress is being made in the construction of reservoirs for the big new Clark Dam at Butler's Gorge. This is designed to impound the waters of the Derwent River, and will be the largest single arch dam in Australia. It is anticipated that storage of water in the dam will be possible this winter.

## Roxborough Gorge Project

THE New Zealand State Hydro-Electric Department has frequently stated that no relief can be expected in the parts where drought causes load shedding, and where the new supplies of electricity are now severely limited, until the Maraetai station is completed. The schedule date is 1951. The station, situated on the Waikato River, is planned for a head of 195 ft.; and five 50,000 h.p. Allis-Chalmers turbines coupled to 36 megawatt Canadian General Electric generators are to be installed. These were ordered in 1945 and the sets have just arrived in New Zealand. They are of the Francis type and will generate at 11 kV.

Tenders are shortly to be called for in connection with the Roxborough Gorge project in the South Island of New Zealand, where power shortage has also been a serious problem in past years. Studies of the rivers leading into the lakes of Wakatipu, Wanaka, and Hawea have shown that it is possible for 320,000 kW to be developed. The plan for the Roxborough Gorge envisages eight 40 megawatt generators. A dam 180 ft. high is to be constructed, and it is estimated that the expenditure of some £A13 million will be spread over the years until 1955, when it is hoped that, at any rate, the first portion of the plant will be in commission.

## Survey of Canadian Water Resources

THE Dominion Water and Power Bureau (Mines, Forests and Scientific Services Branch of the Department of Mines and Resources of Canada) has published Volume 97 of the Water Resources Papers which deal with the surface water supply of Canada. This number contains the results of investigations by the Dominion Hydrometric Survey in the Provinces of Alberta, Saskatchewan, Manitoba, the Northwest Territories and parts of British Columbia and Western Ontario for the climatic years October 1, 1943, to September 30, 1945.

The report contains a short explanation of the organization and scope of the work and 455 pages of stream flow data for rivers and streams within the area mentioned, together with meteorological data, including evaporation, for stations in Ontario, Manitoba and Saskatchewan.

## Cheaper Power in Scotland

THE North of Scotland Hydro-Electric Board has decided to reduce during the winter months the cost of electricity to consumers in Morar, Lochalsh,

Lochcarron, Skye and the Fort William area, districts supplied by water power and isolated electrically from the rest of the Board's area. The new rate is an experiment which relates to "spillover" periods when there is abundance of water supply, and it is hoped to extend the arrangement to other parts of the area when the large hydro-electric schemes under construction come into operation and similar conditions exist.

## India Plans New Schemes

PLANS are under consideration for several irrigation and power projects associated with the Central Provinces and Berar, India. Over a million acres will be served by these new schemes, and approximately 300,000 kW of power would be generated, including power for the development of mining resources. The province of Hyderabad also has considerable schemes afoot, including the construction of a dam over the Kaddam River, a tributary of the Godavri, and a canal 79 miles in length.

## Brazil's New Hydro Projects

ELECTRIC utility companies affiliated to American & Foreign Power Co., operating in Brazil, are now completing four new hydro-electric projects which will increase their generating capacity by 64,400 h.p. to a total of 340,000 h.p. The four projects are (1) the Avanhandava Hydro Electric Development on the Tieté River, State of Sao Paulo, developing a head of 62 feet, where a third 13,410 h.p. generating unit will bring the total capacity to 40,230 h.p.; (2) the Americana Hydro Electric Development on the Atibaia River (also State of Sao Paulo) where an installation of 26,820 h.p. will develop a head of 105 feet; (3) the Areal Hydro Electric Development on the Preto River, State of Rio de Janeiro, where a head of 210 feet will be developed and a total capacity of 24,138 h.p. will be installed; and (4) the Vossoroca reservoir, on the Sao Joao River, State of Paraná, where storage will be provided for a firm 17,165 h.p. capacity from the existing 1,000 feet head Chaminé Hydro Electric plant on the same river downstream.

## The Rôle of Water Power in National Economy

IF proof were needed that water power is often the only key to the improvement of an undeveloped country's economic state, it can be found in recent reports from Pakistan and Brazil. In the first it was shown that minerals exist in considerable quantities in the North-West Frontier Province; alum, chromite, coal, copper, gold and gypsum, are among the natural resources mentioned, but their exploitation depends almost entirely on the provision of electric power.

To provide power in a territory of that nature by means other than hydro-electric would be well nigh impossible, and certainly economically impracticable; but once this is done it becomes feasible to establish large scale industry at remote sites. Moreover, the harnessing of water renders irrigation schemes possible and the application of electrical aids to cultivation would improve conditions for those engaged in the new industries.

Brazil gives news that the coastal territories near Sao Paulo and Rio have become over-populated, while districts such as Minhas in the interior abound in mineral deposits, including vast quantities of iron ore of high quality, which could be worked to better the nation's economy; thus providing employment and, by the construction of new towns, relief to the coastal areas. Again, the development of the hydro-electric resources in the inland regions is the only possible method whereby this desirable condition can be brought about.

## Preserving Welsh Amenities

THE desire to preserve the beauty of the British countryside consistent with the advance of water power schemes is notably exemplified in the Welsh undertakings that are now in prospect. In each of these the planning committee of the county will express its views on the choice of final sites; and it is understood that the concrete power station buildings will, where necessary, be coloured and otherwise treated to soften their appearance in the general picture of the countryside. Transmission lines, wherever possible, will be hidden behind trees and kept off the horizon. The British Electricity Authority has discussed the Snowdon and other schemes with the Council for the Preservation of Rural Wales, and a report will be issued on the subject.

## "Eminently Practicable," But . . .

FROM considerations of harnessing the tidal waters of the Severn it is but a short way mentally (if not yet practicably) to the Mediterranean—and to the dozen miles or so of water from Gibraltar to the coast of North Africa. In this connection a brief outline has recently been given of a scheme proposed by a German engineer, Herr Soergel, of Munich; but another half century must probably elapse before any definite steps are taken in the project because of its obvious complications. The plan has, however, already been examined by some of Europe's leading engineering authorities, and it is held to be eminently practicable, given the necessary conditions, political as well as economic.

Basically a gigantic dam at Gibraltar is envisaged, which would have the two-fold effect of regulating the inlet to the Mediterranean, and lowering the level of the great " inland sea " so that new and extensive areas would become available for agricultural and other developments. An almost unimaginable access of power for both Europe and Africa would thus come into the realm of practical achievement. Administratively the author of this fascinating project goes to the Tennessee Valley Authority for his comparison, but would instead make the controlling body international, acting under the authority of the United Nations. Herr Soergel has himself established an organisation, the Atlantropa Union, with the idea of keeping the idea before those concerned with the control of future power in the two continents.

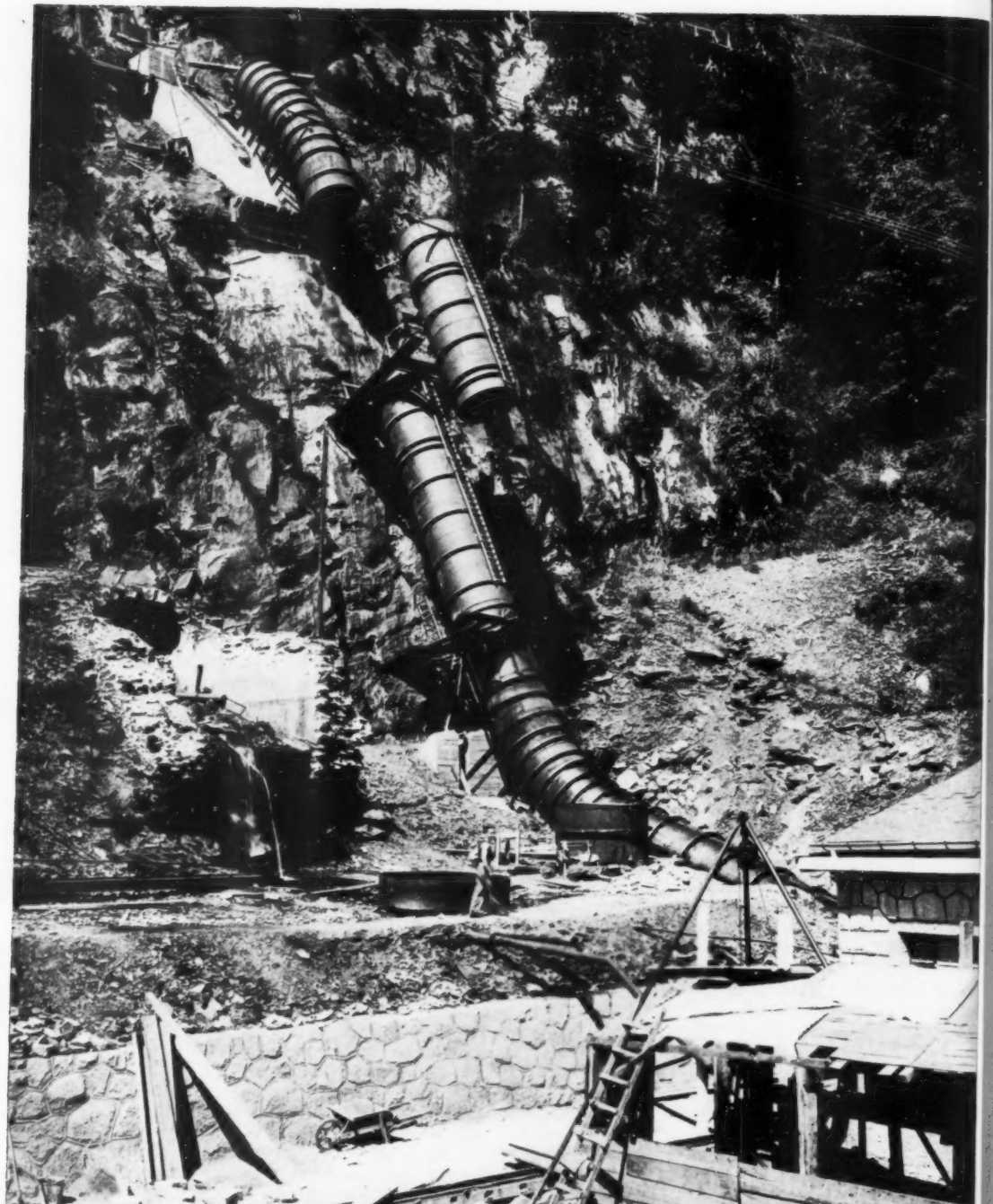


*Photo by courtesy Schneider et Cie*

Penstock at Pont du la Reine during erection

# Design of Buildings

By J. EVERSDON HENDERSON, A.R.I.B.A., A.R.I.A.S.

Comments on some of the influences and problems affecting the design of hydro-electric power station buildings.

*L'agrément d'une station génératrice pose des problèmes de construction. L'auteur souligne la tendance de l'ingénieur et de l'architecte à une suspicion mutuelle qui n'a pas de raisons: elle est un héritage de l'ancienne génération d'architectes qui n'ont pas su marcher de pair avec l'évolution technique des matériaux. Le but premier de l'architecte devrait être de dessiner des projets qui, fonctionnellement corrects, soient aussi agréables à l'oeil; dans ce but l'ingénieur et l'architecte ne devraient être séparés par aucune barriére dans leur conception des ouvrages. L'auteur donne des exemples de bons et de mauvais projets.*

*Comentarios sobre algunas influencias y problemas que afectan el diseño de edificios de centrales hidro-eléctricas por lo que hace referencia a su amenidad. El autor hace resaltar la tendencia tan innecesaria que existe de mantener recelos mutuos entre el arquitecto y el ingeniero; estos recelos son el resultado de una generación anterior de arquitectos que no supieron ponerse a la altura de los desarrollos técnicos de los materiales. El objeto primordial del arquitecto debería ser el preparar un diseño funcionalmente correcto y agradable a la vista, y con miras al logro de este objeto debería existir la mayor cooperación entre el arquitecto y el ingeniero en todos los sujetos estructurales. Se facilitan ejemplos de diseños buenos y malos.*

HARNESSING the latent power of water to serve man's needs has exercised his mind from the earliest times. It was his primary source of power until the advent of the steam engine; and only towards the close of the nineteenth century did steam power temporarily supersede it.

From the utilisation of water power, to drive machinery by direct mechanical means, to the production of electrical power was a natural step. The surprising thing is the delay in exploiting, in this respect, the natural resources of the British Isles.

In the days of the old-fashioned mill, the word amenity was restricted in its meaning and was not bandied about from tongue to tongue. To-day it is on everyone's lips, loosely applied and almost as popular as appendicitis was fifty years ago.

It is proposed in this article, to comment on some of the influences and problems affecting the design of buildings in connection with hydro-electric power stations, so far as their amenity is concerned. A concise dictionary definition of the word amenity is "agreeableness—as to situation, manners, etc." This definition as quoted admirably covers the aspect of the subject with which we are concerned.

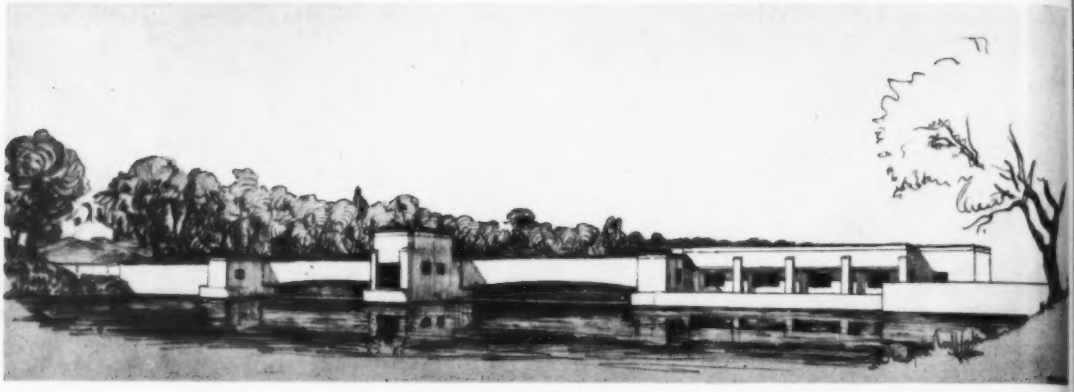
Agreeableness as to situation and manners demands from the designer a high degree of co-ordination of innate ability and training. To have "a feel for the lie of the ground," the capacity to absorb the atmosphere of a district, and be able to produce a harmonious design fulfilling strictly technical requirements is a problem of some magnitude. The types of structure encountered in hydro-electric works are diverse. From almost wholly engineering subjects such as dams, sluice gates, conduits and surge towers, one descends to the factory type power house, to the offices of domestic scale, and to the small sub-station. To add to the complexity of the subject, these structures may be encountered in the most difficult combinations, where scale, type and character are at variance.

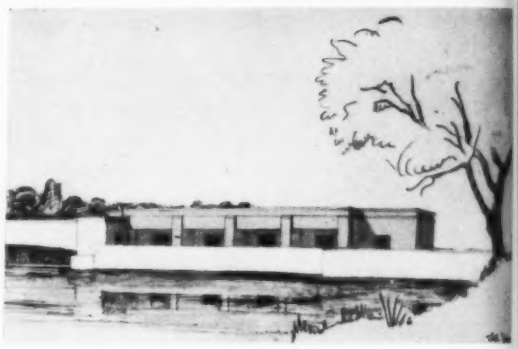
Since hydro-electric work is a highly technical problem, the number of specialists involved is considerable. Each has his own particular problem to solve—and his prejudices. The consulting engineer in charge has a complex technical problem to handle and the solving of it may justifiably make the appearance and amenity of the structures appear to him to be of secondary importance. Unfortunately, many of the technical triumphs are hidden to the public and, as so often happens, the advantages derived from them are soon accepted as commonplace. The finished structures, however, are not. An error of judgment in appearance, character or manners remains an error to future generations who may be even more critical and informed than the present

There is a tendency to mutual suspicion between architect and engineer which is unfortunate and unnecessary. This suspicion is a legacy from an earlier generation of architects who failed to keep abreast of the technical developments in materials, then taking place, and insisted on using motives of a bygone era. The architect of the pseudo-façade days is passing, or has passed. The present generation of architects has had sufficient basic technical training in engineering subjects to be able to comprehend the aims of the various specialists. They have also a knowledge and feel for the use of new materials, as their predecessors had, when stone and wood were their main sources.

Special mention is made of this point as the bearing on this subject is direct. Co-ordination is the keynote of successful design in these schemes and to have co-ordination there must be mutual confidence.

The first aim of the modern architect is to produce a functionally correct design to meet his client's requirements. Secondly it should be pleasing and satisfying to the eye. If this is his aim there should be no barrier between the approach of architect and engineer to any structural subject, and the importance of getting together at the earliest possible stage in any scheme, cannot be over emphasised. The team of

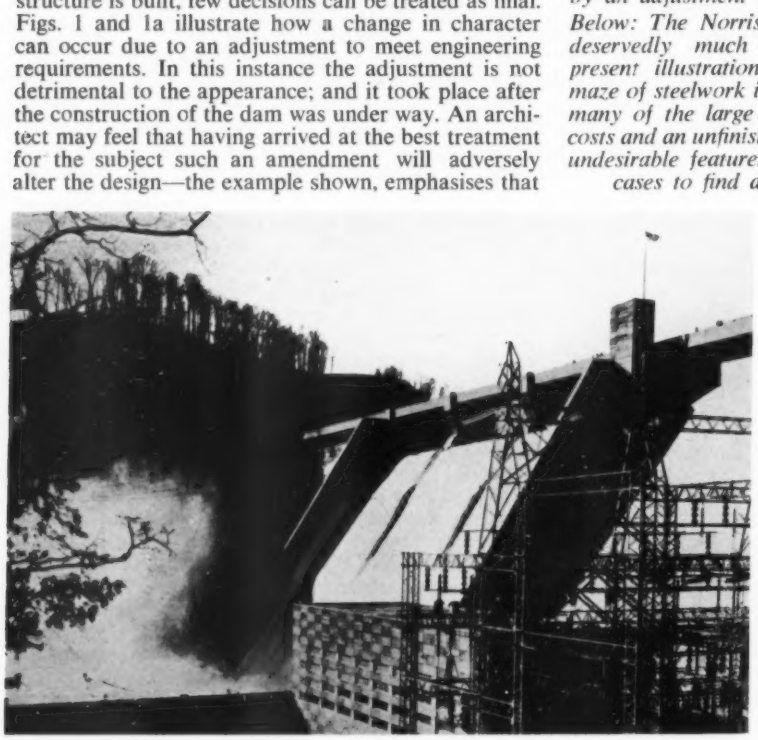




*Figs. 1 and 1a: Sketches of Pitlochry Dam and Station from upstream. A change in character has occurred by an adjustment to meet engineering requirements Below: The Norris Dam in the T.V.A. Scheme—a deservedly much quoted design to which the present illustration does not do full justice. The maze of steelwork in the foreground is reminiscent of many of the large American schemes. Maintenance costs and an unfinished appearance make these lattices undesirable features. It should be possible in many cases to find a less conspicuous alternative*

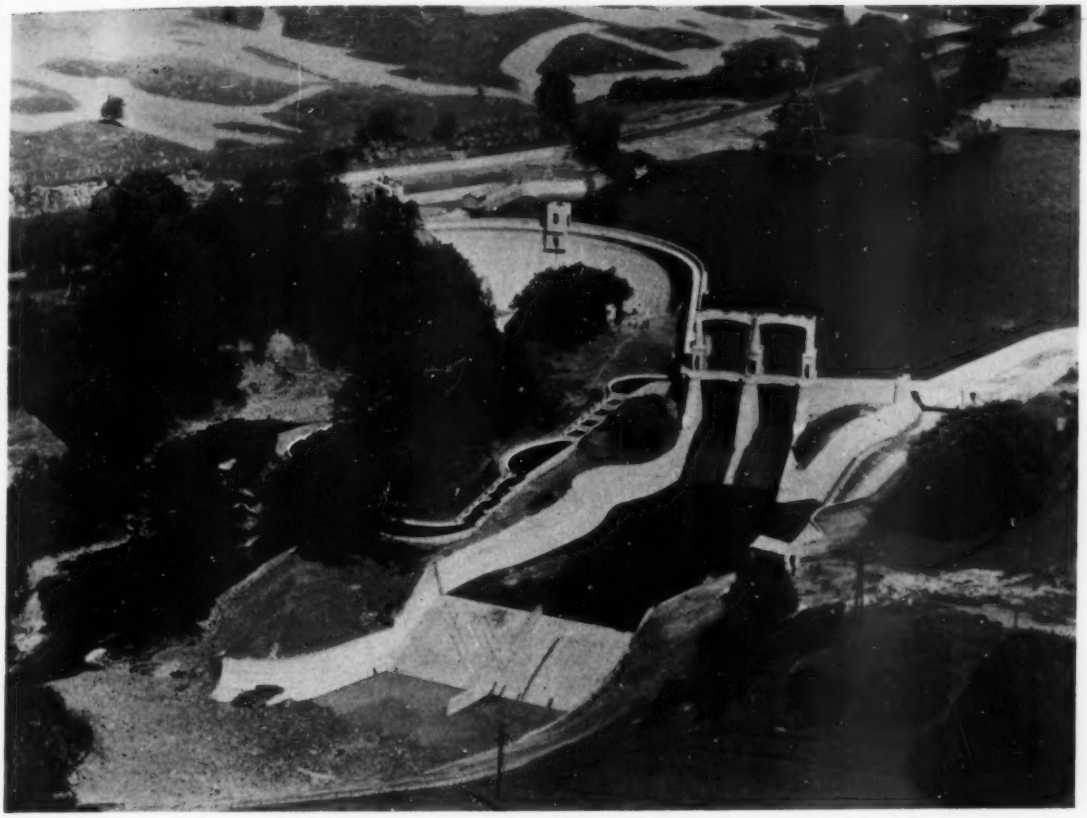
engineer, architect and specialists should be brought together and the proposals thoroughly ventilated before a pencil is set to paper. This is the foundation of good design and amenity. A solution to any problem is a compromise of conflicting requirements and concessions must be made. If the aims or requirements of each person or adviser are made known at the outset, the best compromise can be achieved. Although buildings are sited to meet technical requirements, minor adjustments may be possible at an early stage which might make the task of blending with the surroundings more easily accomplished.

Any architect acting as a consultant on hydro-electric work must be willing to accept considerable restriction on his freedom of thought as even comparatively minor details may be controlled by technical necessity. He must be adaptable to changing circumstances, as experience in this work shows that until the structure is built, few decisions can be treated as final. Figs. 1 and 1a illustrate how a change in character can occur due to an adjustment to meet engineering requirements. In this instance the adjustment is not detrimental to the appearance; and it took place after the construction of the dam was under way. An architect may feel that having arrived at the best treatment for the subject such an amendment will adversely alter the design—the example shown, emphasises that an open mind must be preserved in dealing with such circumstances.

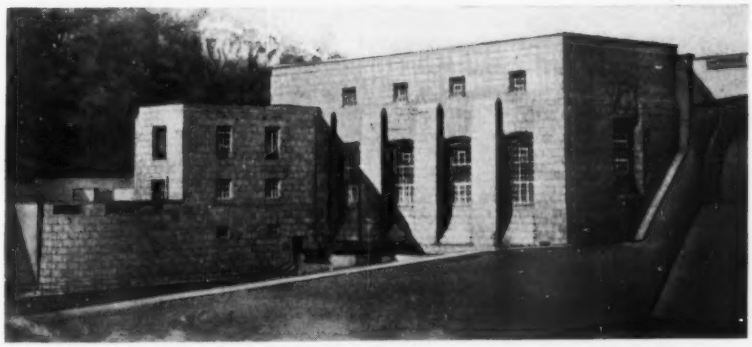


The general trend in the treatment of recent hydro-electric structures has been to clean up the designs and omit embellishments, many of which had no structural significance and were of poor ornamental quality. It is gratifying to note that in general the character of the buildings is allowed to express itself naturally in the elevational treatment; and that variety is being obtained by judicial emphasis, or repression, of the various structural components.

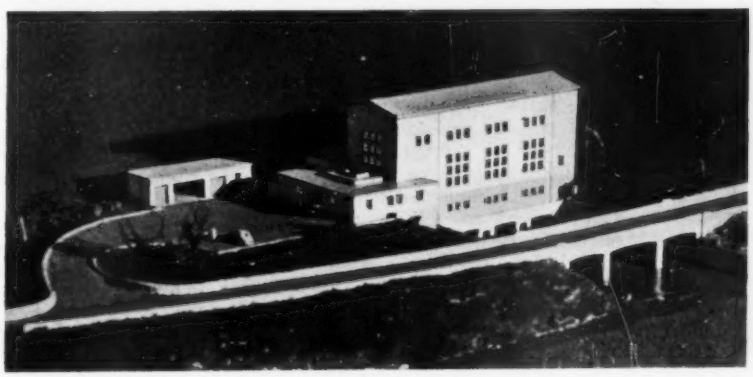
Although not strictly a building in the usual sense of the word, dam structures come within the scope of this



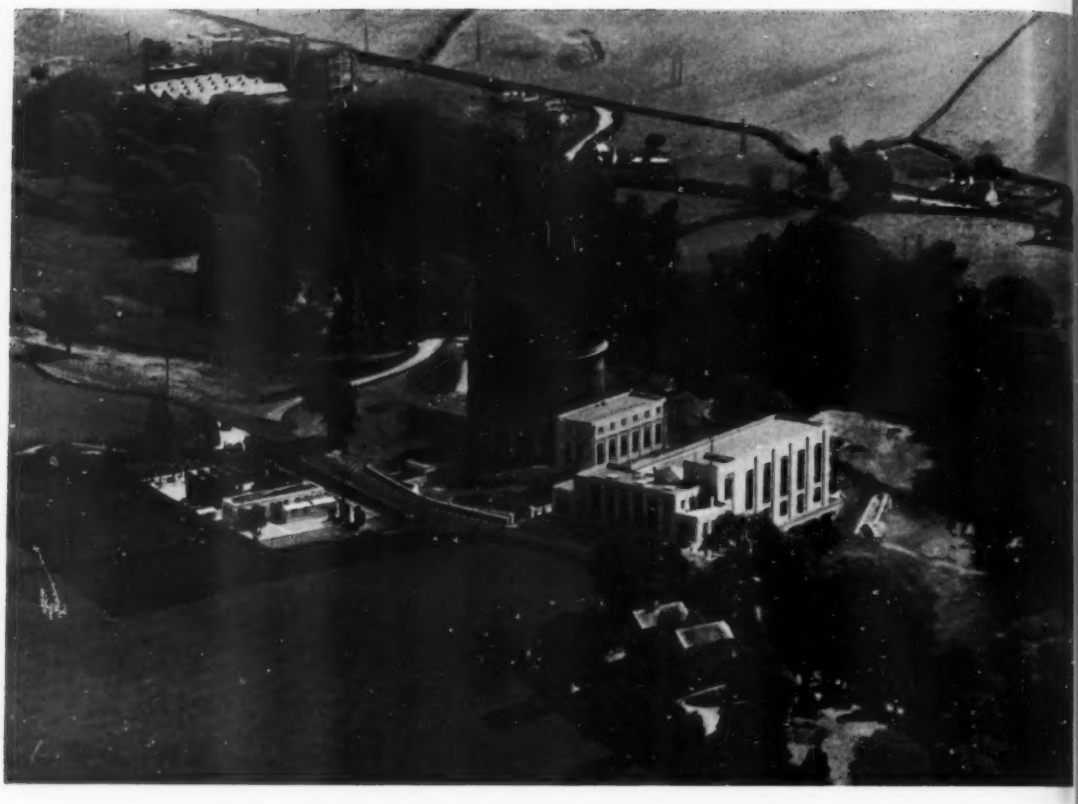
*Top: Tongland Dam and Headpond. The picturesque and slide rule are here happily combined in a delightfully free treatment where the natural features of the ground have been fully exploited. The flowing shapes are a change from the usual rather rigid treatments*



*Right: Pitlochry Power Station and Dam. The perspective shows the masonry effect obtained by the use of precast concrete slabs with an exposed granite aggregate finish. The feeling of solidity aimed at is very marked*



*Bottom: Model of a preliminary design for Errochty Power Station. A straightforward fulfilment of technical requirements*



article. Their size makes them impressive spectacles. Siting, water storage and type of structure are almost wholly dictated by mathematics and physical considerations. Improvement on the basic design must be achieved without excessive expenditure. An examination of existing structures, however, reveals that some very pleasing designs have been produced. The best of these rely on simplicity and good proportion for their success. Since so much of the structure is decided by calculation, it may appear that any good proportions have been achieved by accident rather than design. It is, however, possible to improve the general proportions of the whole by careful adjustment of a part only.

The Norris Dam in the T.V.A. Scheme is a well known example of good design. It is a recommendation of strong simple lines and good proportion. Did you realise, however, to what extent the design of the spill-way bridge contributes to the whole? The spill-way openings, the intermediate piers and the depth of the girder are subsidiary to the main structure but their effect can be gauged from the illustration.

An entirely different type of treatment is illustrated in the Tongland Dam for the Galloway Scheme in Scotland. It is difficult to imagine a more delightful picture of an industrial undertaking. Although it appears to have arrived out of the nature of the ground, it is obviously the outcome of careful thought and sympathetic handling. Can we hope that the informality of this treatment may be emulated elsewhere? Present day designs are clean and simple, but there is a certain rigidity apparent which is unfortunate.

*Tongland Power Station: Fed by underground pipeline, the surge tower was essential. Too big to hide, it has been treated quietly and is fairly inconspicuous, not being skylined as in some cases. The planting between the road and the Sub-Station opposite the surge tower had not had time to develop when the photograph was taken. Clusters of transformers, however, are as unsatisfactory aesthetically as a wireless chassis in a drawing-room*

It is not possible here to deal comprehensively with the design of power stations, even if only the external appearance has to be considered. The variations in setting and internal make-up are too numerous. Two broad divisions of siting may be noted — when the station is beside or part of the dam, or where it is on its own. In the first case, the station is always subsidiary to the dam. The elevational treatment is more often plain and bold, and in keeping with the dam itself.

In the case of the Norris Dam, the station is sited at the base. The treatment is simple — a plain rectangular building with horizontal emphasis given to the windows; and the results are more pleasing than could have been achieved by normal vertical proportions. The squared pattern on the wall surface, obtained by alternating the vertical and horizontal boarding of the shuttering at each lift, has added texture and scale to the building. This is a typical example of a power station designed to agree with its parent structure.

A combined example of another type is shown in the perspective of the Pitlochry power station and

*Above: Albula, Switzerland, 1909. Rebuilt 1945. This is a case where a traditional type treatment is justified as it fits in so well with the surroundings. A modern treatment would have been rather conspicuous*

*Right: Lilla Edet, Sweden. A design expressive of its purpose but lacking the lightness of treatment usually associated with Swedish architecture*

dam. This is at present under construction by the North of Scotland Hydro-Electric Board as part of their Tummel-Garry scheme. This scheme deserves particular reference in this article as it was the subject of most heated controversy on the question of amenities, the subject of a public inquiry and much Press publicity. The charges by the objectors were spoliation of the scenery in a manner detrimental to the tourist industry of the district.

In these circumstances the amenity question was much wider in its aspect and involved the replacement of bridges, sports grounds, public walks and other attractions. In Scotland, historical association rears its head to challenge change in a way not encountered in a developing land such as Australia or America. This is inevitable. In open, undeveloped country no preconceived style of building exists. Subject to availability of materials, the designer has complete freedom of choice. In a built-up area—and Britain in general is one by comparison—the traditions and character of the district developed over centuries,

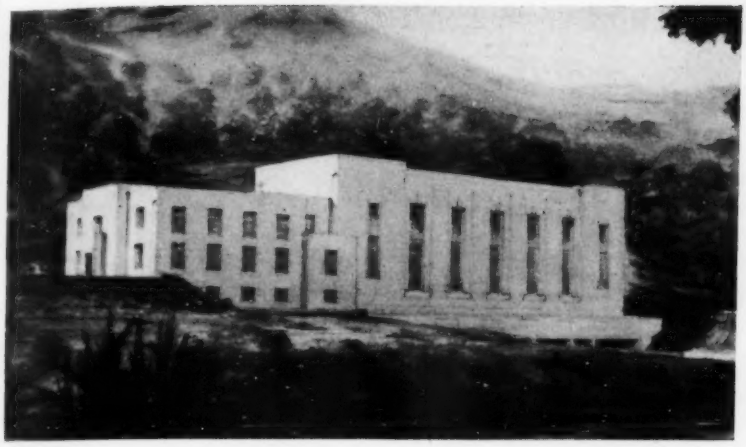
*Above: Fribourg, Switzerland. A pleasant traditional type building but not suggestive of a power station. The treatment is too domestic in character*

*Left: Verbois, Switzerland. 1938-43. The plain rectangular shapes relieved by the tall vertical windows are more in keeping with the character of a power station than the station at Fribourg. Some relief from the straight lines could have been introduced with advantage. The vertical emphasis is however slightly overdone*

cannot be ignored.

Thus, the North of Scotland Hydro-Electric Board and its advisers have had to give more than usual consideration to the finished effect of their schemes. They have to satisfy a large number of individuals outside the Board before final approval is given. In the Tummel-Garry scheme it was decided to clothe the concrete structures of the stations in precast concrete slabs with an exposed granite aggregate surface. The granites to be used are pink and grey. Many sample slabs were prepared varying in colour and texture before the correct effect was obtained. The finished structures will have the appearance of real stone. Thus, the first step towards harmony with the surroundings was taken.

This decision considerably affected the elevational treatment of the buildings. A masonry effect must of necessity give an impression of more sturdy stability than that expected of steel and concrete. In the Pitlochry station it will be noted that the building acts as a finish to the dam and, to be satisfying, must



*Clunie Power Station shows much more grace and dignity than the usual power station but at the expense of honesty of expression*

give an impression of buttressing. The aim of the architect has been to create an impression of mass, as in earlier designs there was a distinct feeling of weakness at this point. In this station the staff offices are incorporated. In such cases there is always the difficulty of reconciling the domestic scale of the office windows with the large openings required for the power house itself. There is no hard and fast rule for overcoming this. Here a straightforward treatment has been adopted which is fairly successful.

As examples of free standing stations the illustrations of the Tongland station of the Galloway Water Power Company and a proposed design for a station at Errochty in the Tummel-Garry scheme are an interesting contrast in setting. At Tongland the dominance of the surge tower is considerably reduced by the bank of trees in the background, into which it merges when viewed from the ground. It is quietly treated and the crisp contrast of the buildings helps to throw it into the background.

The buildings are well proportioned and the introduction of the tower has helped to bridge the change of scale in the fenestration. In this case the contrast of horizontal and vertical lines of the building shows to advantage against the round shapes of the countryside. The proximity of the switching station to the road can only be described as unfortunate from an æsthetic point of view.

The Errochty station is sited in an area of birch trees and hills. The difference in treatment from the previous station is interesting. No style has been adopted and the exterior of the building is a straightforward development of the internal arrangements. The fenestration is practical. At the same time it is arranged to give a nice balance of void and solid. It is unlikely that this design will be adopted. The author would like, however, to have seen it fully developed and carried out, as it has a freshness of treatment not apparent in any designs yet built in this country.

The smaller buildings, such as sub-stations and control rooms, should receive the same care in design as the larger buildings. Some designs for these can only be described as brick built sheds. To call in an architect after the electrical engineer has worked everything out to the last inch and ordered his equipment is illogical. The appearance of any building should be considered from the start of the design. Fulfilling requirements in a pleasant way is design, and there is no excuse for an ugly building.

Apart from buildings there are some amenity problems which are much more conspicuous. Switching stations with their mass of overhead cables and pylons dwarf any building in their vicinity; thus choice of site is of the utmost importance. They are not temporary erections, so any slight addition to the initial expenditure involved by siting them off the beaten track, is justified. At present they cannot be made to look attractive.

In a number of schemes abroad the feed pipelines to the stations are left exposed. These can be seen from miles away, long before the station itself becomes visible. In this country there is an intention to earth them over wherever possible.

It will be noted that the need for the closest co-operation between all parties has been stressed throughout this article. This is not a personal opinion only. A study of the continental and other examples reveals that, apart from the T.V.A. Scheme, few stations or buildings show the orderly planning and grace which one has the right to expect when such heavy capital outlays are involved. Although the standard of design is improving, few hydro-electric buildings indeed are worthy of inclusion as examples of contemporary architecture.

Hydro-electric power is a product of our age and a milestone in the development of man. In a period of transient architecture the buildings housing this power will be permanent and among the few monuments of this time left to future generations. In these circumstances it behoves us to ensure that, inside and out, they are worthy of this distinction.

*The author is indebted to the United States Information Service, the American Embassy, and the British Electricity Authority (South-West Scotland Division), for the use of the photographs of the Norris and Tongland schemes respectively; also to the North of Scotland Hydro-Electric Board for permission to make use of material relating to their schemes in the Tummel-Garry area.*

*He is particularly grateful to the Hon. Lady MacGregor of MacGregor for the photographs of the Swiss and Swedish stations, which have not previously been published.*

## NORWEGIAN STUDENTS' VISIT

A party of forty-six Norwegian civil engineering students from the Technical University of Trondheim, Norway, under the leadership of Professor Laerum, have recently been visiting a number of engineering works and construction sites in Great Britain.

The tour, which was arranged by the British Council, included the hydro-electric project at Loch Sloy, where both the dam and the power station are approaching completion.

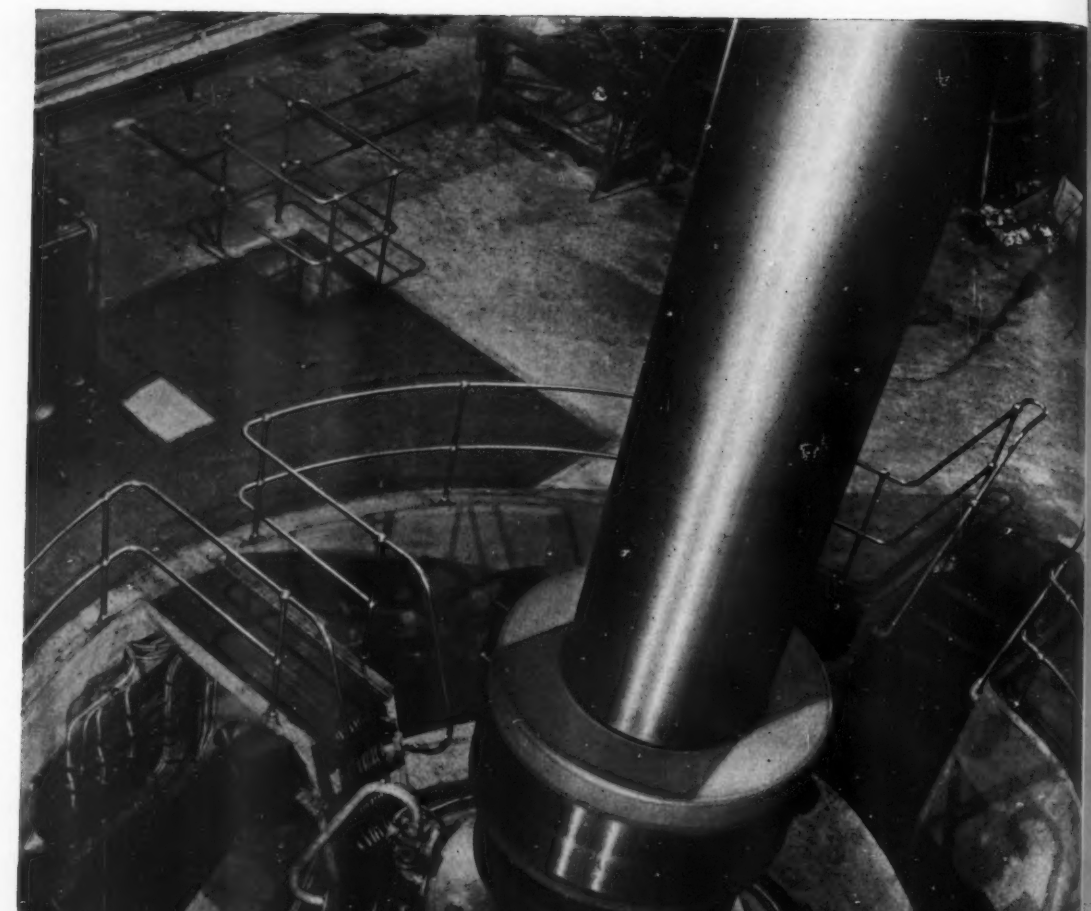


*Photo by courtesy Schneider et Cie*

Génissiat: *A dramatic view of number one unit*

# Génissiat

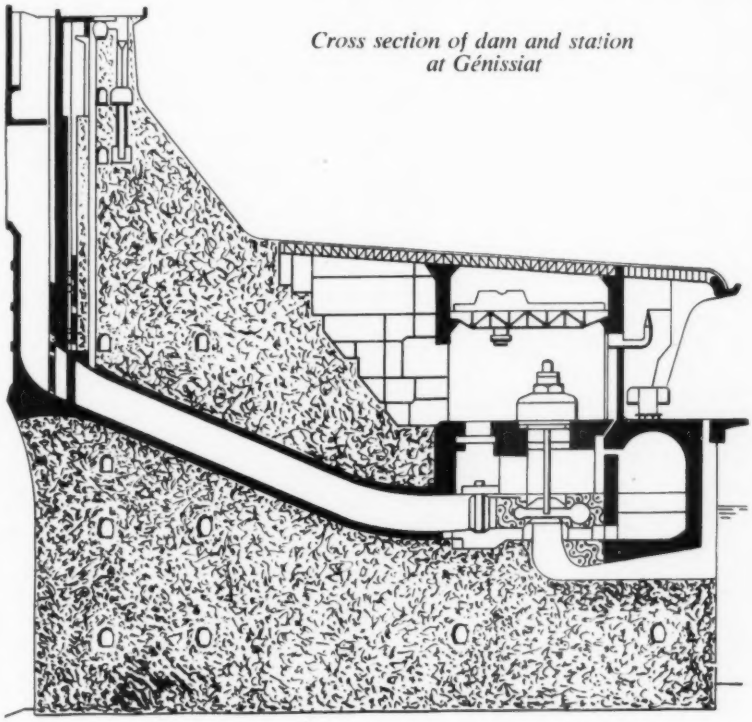
By R. H. E. RYLEY, A.M.I.E.E. A picturesque account of a project which is one of the most important factors in France's post-war development plans.

*Une description pittoresque des installations de Génissiat, en voie d'achèvement dans la vallée du Rhône non loin d'Aix-les-Bains et d'Annecy. C'est le plus grand ouvrage de béton en France, et, en raison du besoin impérieux d'électricité à bon marché pour toutes les branches de l'industrie, l'un des facteurs les plus importants du plan français de reconstruction. Deux turbo-alternators, comprenant chacun une turbine Francis à axe vertical de 100 000 hp, débitent déjà. Une fois la station terminée, quatre groupes semblables de turbo-alternateurs produiront 1,500 million kWh par an.*

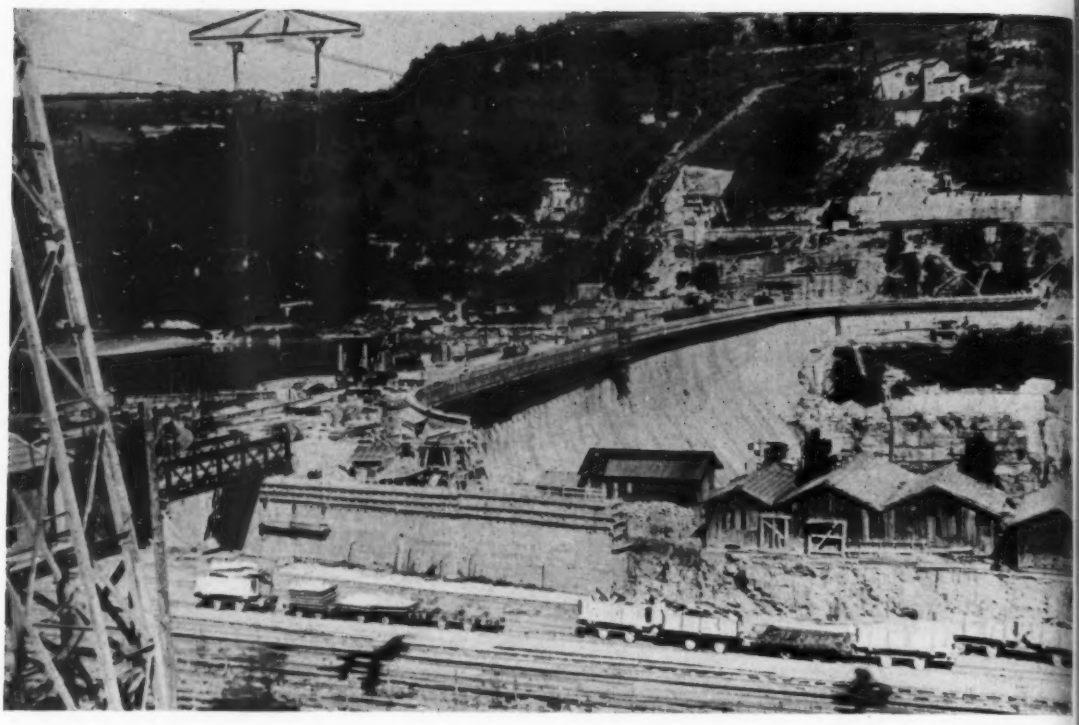
*Una descripción muy pintoresca del proyecto Genissiat ahora en sus últimas fases de construcción en el valle del Ródano, cerca de Aix-les-Bains y Annecy. Constituye la mayor obra de hormigón de Francia y es uno de los mayores factores del planteamiento de recuperación de la postguerra de Francia, debido a que es esencial que todas las industrias del país puedan contar con electricidad barata. Ya funcionan dos turboalternadores, cada uno comprendiendo una turbina Francis de eje vertical de 100.000 h.p.; cuando el proyecto Genissiat haya sido completado, se calcula que la central generá 1.500 millones de kWh por año utilizando cuatro grupos de turboalternadores parecidos.*

IN the picturesque Rhône Valley, not far from Aix-les-Bains and Annecy, a vast civil and electrical engineering project is nearing completion. The largest concrete work in France has been achieved, and the giant mixers can be moved elsewhere. The army of workmen, once 4,000 strong, can view their result with pride. The Moroccans and Senegalese, who worked day and night with displaced persons from Eastern Europe and nationals of nearly every European country, can take their tower of Babel upstream to Sault-Brénaz where a complementary scheme is planned—for Génissiat is nearly finished.

As long ago as 1901 a commission was created in France to survey the Rhône Valley, with particular reference to hydro-electric projects, navigation, and agricultural needs. It was not until 1934, however, that the *Compagnie Nationale du Rhône* was granted a concession to create a dam at Génissiat. Two years of intensive planning followed and preparatory work was commenced in 1936. By spring of 1939 progress was sufficient to allow the most diffiult operation to be successfully tackled—the cutting of the river. This step, once taken, had to be followed up without delay or hindrance, and already impending war was casting its shadow. After the cutting, the dam rose steadily and continued to do so during the first few months of the war. With the shock of the armistice, however, and the dreadful uncertainties that followed, work was reduced to a minimum; and the labour, so skilled in



*Cross section of dam and station at Génissiat*



*General view at top of dam. Below: The main overflow looking upstream*

fashioning concrete caissons, was drafted to make fortifications. Deprived of cement and severely curtailed by occupation conditions, the work nevertheless continued sufficiently to become, soon after the liberation, the largest concrete work yet achieved in France. In normal circumstances the work would have been completed in about a quarter of the time.

The site is seven kilometres downstream from Bellegarde and 50 kilometres from Geneva. It is in a miniature "Grand Canyon" and particularly suitable for many reasons. The cliffs are of strong limestone rock and there is a plateau on either side making a future system of navigational locks a comparatively easy proposition. At this position the dam creates a head of water of 60—69 metres with a flow of about 800 cubic metres per

metres the water gains considerable momentum. It is directed jet-like back into the middle of the river, not at river level, but from a height of about 25 metres, creating a beautiful arch of foam and spray. The flow may be as much as 2,700 cubic metres a second, and the noise and rush of air caused by it is at once deafening yet fascinating in its magnitude. It is a wonderful spectacle in sunlight, which causes an endless succession of ever-changing rainbows and hues.

The second overflow has barely half the capacity of the first, but has a double function. Apart from releasing flood-water it is used to disperse the accumulation of silt and gravel at the base of the dam. For that reason it is located well below surface level of the lake and is subterranean in the left cliff. It also discharges below water level on the downstream side of the dam. Little of it can be seen on either side by the casual observer, but it plays quite an important part in a river such as the Rhône, which carries appreciable suspended matter.

The turbine house is at the base of the dam and extends a little into the cliffs at both sides. The control room is above the turbine house. There are six water intakes,

*Main overflow looking downstream. Below: Close-up of Francis water-wheel of No. 1 unit*

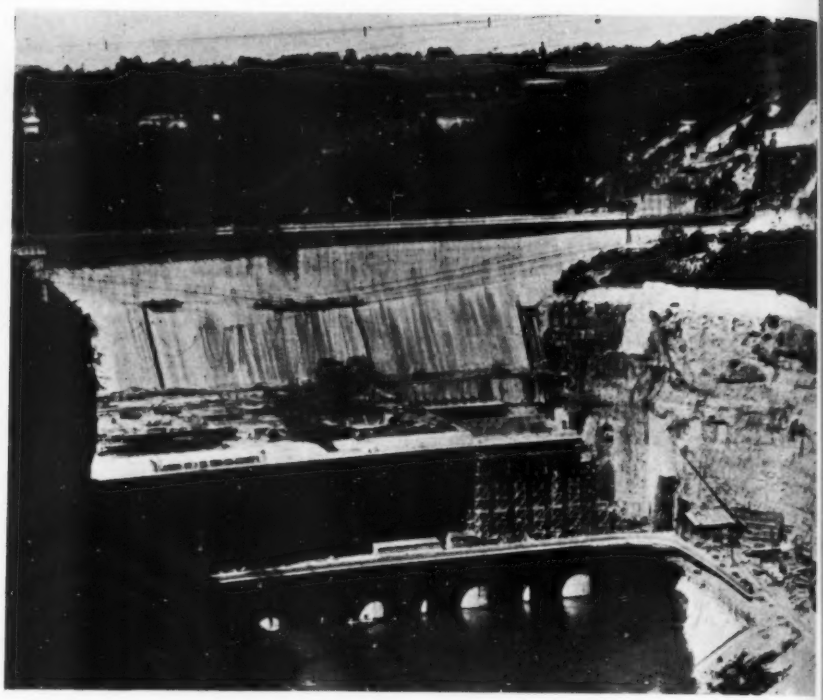
*Photo by courtesy Schneider et Cie*

second. This is equivalent to a power of some 400 megawatts.

It is calculated that the water retained by the dam amounts to about 12 million cubic metres. It extends back for nearly 23 kilometres, and the enterprising French have been quick to take advantage of the beautiful lake which has appeared, as if by magic, in the last few months. Bathing *plages* and yachting clubs have been formed upstream from the dam.

The dam is 104 metres high from cliff to cliff. It is 100 metres thick at the base, but only 9 metres at the top. There are two overflows, one of which is particularly spectacular. It is on the right bank of the river and is a long channel of semi-circular section. The water is drained off about 50 metres upstream from the dam and flows at a moderate pace for some 250 metres down the smooth surfaced concrete. Then the drop becomes very steep, and for the last 100

*General view of the dam showing the turbine house, which extends into the cliffs at both sides, in the course of construction*



*Below: An unusual view of the main overflow re-entering the river in the form of a large jet*

one for each of the ultimate turbine sets. The intakes are protected by a 10 cm. grill, behind which the control valve operates. The water continues through the body of the dam in a metal pipe nearly 6 metres in diameter, and terminating in butterfly valves.

So far as the turbo-alternators are concerned, five identical sets have been ordered. Two are already in commission and the remainder are in an advanced state of construction. Each comprises a 100,000 h.p. vertical axis Francis turbine, with a direct coupled 70,000 kVA 3-phase alternator. The full power is developed with the water at a maximum head of 69 metres. Generation voltage is 15 kV, which is raised to 220 kV by separate transformers of 70,000 kVA capacity for each group.

This project is one of the most important factors in France's post-war recovery planning, cheap electricity being so vital in every industry. To this end Génissiat is expected to contribute 1,500 million kWh *per annum* when four groups are running.

# Choice of Literature

By S. P. HUTTON, M.Eng., A.M.I.C.E. (Lecturer in Hydraulics, City & Guilds College, London). Text books on the fundamental principles and the general rules of good practice in the civil and mechanical engineering branches of hydro-electricity.

*Une revue des ouvrages techniques traitant des principes fondamentaux ou des régles générales de la pratique dans le génie civil et la construction mécanique de l'hydro-électricité. La littérature sur ces sujets est très vaste; l'auteur a groupé sous cinq titres principaux les livres de la bibliographie qu'il indique. La valeur de cette étude sera très appréciée des nombreux ingénieurs qui, en raison du manque de main d'oeuvre technique et du developpement de l'hydro-électricité dans le monde entier, sont confrontés pour la première fois par les problèmes des travaux hydrauliques.*

*Una revista de los libros de texto disponibles versando sobre los principios fundamentales y las reglas generales correctas en las secciones hidroeléctricas de la ingeniería mecánica y civil. El autor ha examinado un gran número de obras versando sobre este sujecto y los libros que lleva incluidos en la lista de referencia están agrupados bajo cinco capítulos principales. Este estudio será de gran valor para muchos ingenieros que tienen que resolver problemas de ingeniería hidráulica por primera vez, debido a la escasez que existe de mano de obra técnica y debido también al desarrollo constantemente creciente de proyectos hidroeléctricos en todas partes del mundo.*

WITH the development of hydro-electric schemes all over the world and the present shortage of technical labour, many engineers are finding themselves confronted with hydraulic engineering problems for the first time. The electrical engineer with a wide knowledge of steam power stations may now be required to deal with the problems of a hydro-electric scheme, and to do this he will need to acquire a general idea of the civil and mechanical engineering aspects.

There is, therefore, a real need for guidance in the choice of literature on hydro-electric engineering. This review has been made of the available text books on both the fundamental principles and the general rules of good practice in the civil and mechanical engineering branches of the subject.

The books are shown in the list of references under five main groups, and are the result of careful selection from a large number, many of which are now out of date. Those listed are, in the writer's opinion, the best selection for the student and the practising engineer. It is not recommended that any attempt be made to read all of them, but the grouping is intended to give the reader a choice which will depend on his existing knowledge and the availability of the works. Those marked with an asterisk are recommended and should best provide the reader with the essentials of water power engineering. With few exceptions these are recent editions, and so they should be easy to obtain.

**Functional Aspects**

The reader's first requirement will be an explanation of the functions of a hydro-electric scheme in a way which emphasizes the inter-relationship of the various components. Most text books, in attempting to give a clear picture of the functional aspects, become quickly immersed in terminology and a wealth of practical detail before explaining the principle sufficiently. Obviously a certain amount of detail is necessary even at such an early stage, but the reader is warned that although the functional aspects of water-power engineering are the same all over the world, the practical details are different. The European schools of Swiss, German, French and Swedish practice differ considerably from the American in detail, and it is inadvisable to become involved in such aspects at an early stage in one's technical education. The practical details can come later and will best be learned by experience.

**Basic Instruction**

A very short and simple book explaining the functions of a hydro-power scheme, together with the terminology used, is by Greene[1] and was originally written for students at Princetown University. It is a most elementary book but explains the functional aspects clearly, and gives the engineering terms by which the various components are known. It should not take long to assimilate but will save the layman much time and misunderstanding on progressing to the larger and more detailed books.

Another general book is by Barrows[2], and was originally written for the use of post graduate students in hydro-electric engineering at the Massachusetts Institute of Technology. The third edition has been revised and brought up to date in the three chapters dealing with water power development in the world, hydrology, cost and value of water power. The first chapter on water power development, distribution and use is particularly worth reading and the figures quoted are correct up to 1942. The chapter on hydrology and stream flow is based on American figures, and allowance should be made for this because hydrological data can differ greatly in other continents. The descriptions of turbines, dams, power-house equipment and accessories are drawn mainly from American practice and do not contain the most modern examples. Little attention is paid to pure hydraulics in its application to flow in either

open channels or in closed conduits. The recently revised chapter on cost and value of water power is interesting and illustrates the importance of the economic factors. The book should give the reader a good idea of the various problems encountered in water power engineering in America but it is not wholly up to date.

A similar book written by Gibson[3] and published in England is in some ways better arranged and more easily read, but it suffers from the disadvantage that it is rather old fashioned.

**Principles and Practice**

Having a general idea of the subject it is profitable to turn to the so called handbooks on hydraulic engineering. They are not only handbooks of current practice but also include fundamental principles. The most recent of these *compendia* is that edited by Davis[4], consisting of twenty-three chapters on specialized subjects contributed by eighteen American experts. It presupposes an elementary knowledge of hydaulics and is intended to serve both engineers and engineering students. As the preface remarks—" To the engineer it furnishes practical reference data on the planning and design of modern hydraulic works; to the student it furnishes in one volume, complete texts on hydrology, water supply, sewerage, water power, hydraulic structures and other related subjects which are usually presented in engineering courses." It is the most recent book of its kind and chapters 1 to 13 inclusive will be of particular use to the hydro-power engineer. Chapters 15—22 deal mainly with water supply irrigation and municipal engineering and are not so relevant. The final chapter on hydraulic models by Hickox of T.V.A. is again of interest to the hydro-electric engineer.

Spillways, stream bed protection works, spillway crest gates and high pressure outlet works are particularly well described and the whole book is well illustrated.

Another similar but more detailed book is by Creager and Justin[5]. Whereas Davis deals with several branches of hydraulic engineering, this book is concerned solely with hydro-electric engineering and is therefore able to go into the various aspects in more detail. However, it contains less fundamental hydraulics than Davis's but gives more constructional details and empirical design rules. Although an older book it is believed that it is being revised and reprinted very soon. Both books are very American in scope and say little about European practice. A comparable handbook in German of continental practice is by Ludin[6], which though older may be of interest when the illustrations are compared with those in the American handbooks. There is sufficient material in any of these handbooks to teach the student a great deal, and they will also be of use for reference as they contain bibliographies on various specialised subjects.

**Advanced Technology**

The remaining groups 3, 4 and 5 are intended for the practising engineer who wishes to obtain information on the more advanced and specialized branches where details as well as principles are becoming important.

Group 3 contains what is probably the classic book on hydro-electric engineering, and although now rather old it is still valuable to the student. It was originally written in 1929 by Dr. Schoklitsch[7] and was so well received that a translation was made under the auspices of the American Society of Mechanical Engineers, and it was published in English in 1935.

It is interesting to note what the author said in his original preface—" The book is presented as a text book for engineering students and as a reference work for practising engineers. In spite of the extraordinary abundance of literature on hydraulic structures, a modern comprehensive exposition of the subject has been lacking, *i.e.*, a treatise in which one could inform himself quickly and yet thoroughly on any special branch of the subject." This work is still the best attempt at such a treatise and if a book on similar lines, but containing more modern illustrations were written, it would be ideal. The first volume covers the fundamentals of meteorology, hydrology and hydraulics, soils and soil mechanics, building materials, water supply engineering and sewage. The chapter on hydrology and hydraulics is recommended to the hydro-electric engineer as it contains more fundamental hydraulics than any of the books so far mentioned. Volume two is the main work on design details and describes dams, outlet works, canal intakes, hydro-electric plant, land reclamation, river engineering and waterway engineering: it contains many fine photographs of continental schemes and long accounts of experimental work on models.

A more recent and specialized book on hydraulic structures is that by Creager, Justin and Hinds[8]. These authors are well known American engineers and their book is probably the best modern book on dam construction. It is in three volumes, as indicated in the list of references. Volume one dealing with general design problems is recommended. The other volumes give a more detailed analysis and description of the various types and methods of dam construction. It is well illustrated from American practice, and perhaps as a result, discusses earth and rock-fill dams in great detail. The bibliography at the end of each chapter is particularly useful.

**" Turbine Design "**

Of the books specializing in the mechanical and hydraulic design of water turbines most of the best are continental, and have not been printed in English. The most recent of these is by Tenot[10], who was for many years chief engineer of *Charmilles*. It is written in French, is in three volumes, and is remarkably complete. The classic book has been by Thomann[9]; but Tenot seems to combine the best features of the German work, while contributing more recent information on French and Swiss practice.

Tenot's first volume discusses fundamental theory and the laws of dynamic similarity and describes various types of water turbines; there is also a brief account of the construction and applications of hydraulic machines.

Volume two begins with a description of hydraulic research laboratories and methods of measurement, and goes on to show how the preliminary assessment of a hydro-power scheme is made from topographical and hydrological data. The rest of this volume describes the detail design of Pelton wheels and the various constructional methods of different firms.

Volume three, in a similar way, describes methods of designing Francis and propellor turbines in great detail. Two methods of designing propellor turbines are illustrated, one using velocity triangles and the other, more recent, by using aerofoil data obtained

from wind tunnel tests. There is also a very good chapter on cavitation describing experiments which were made at *Charmilles*. The book finishes with illustrations and examples of modern Francis and propellor turbine installations. It is the most detailed and complete work on water turbines yet available.

Another interesting little book on propellor turbines for high specific speeds is by Kaplan and Lechner[11]; it makes some interesting remarks on draught-tube design and model tests, and seems to contain original ideas which might still be profitably pursued to-day.

A recent American book by Wislicenus[12] describes the fundamental fluid mechanics of turbo-machinery in great detail. It is written by a man with considerable theoretical knowledge that is tempered by his awareness of differences between theory and practice. It affords thoughtful reading for the specialist, but does not give many actual design details of turbines.

Although Schoklitsch[7], Tenot[10], and some of the other books mentioned, devote much space to hydraulic theory the engineer may wish to refer to literature concerned solely with flow problems. With this view in mind the books in Group 5 have been recommended for those requiring specialist knowledge on the basic fluid mechanics and its applications to hydraulic engineering.

Hunter Rouse[13] on fluid mechanics for hydraulic engineers provides a most useful collection of data from aerodynamics, hydrodynamics and applied mathematics. The book has been written for hydraulic engineers and covers a very wide field.

Bakhmeteff[14] in his book on open channel hydraulics is unrivalled, and although not always easy to read it is worth careful study. Both these books are published in the A.S.M.E. Monograph series.

Allen's recent work[15] on scale models in hydraulic engineering filled a great need for a text book on an important aspect of water-power engineering. It is a valuable source of information and contains an extensive and well indexed bibliography.

A large field of literature has been examined in producing this article, and the beginner wishing to educate himself in hydro-electric work would take a long time to cover even those books listed in the references. Many of them, however, are only intended for the reader requiring more specialized knowledge in certain branches; for general purposes any of the references 2, 4, 5 or 7 will give a good idea of hydro-electric engineering.

## NEW BOOKS

Since this article was written two more books have become available:—

1. Hydro-electric Engineering, by Gerard, Pitman, 1949.
2. Technische Hydraulik, by Dr. Charles Jaeger, Zurich, 1949.

The former belongs to Group 1. The latter is a specialist book for Group 5, and we hope to review it in a later issue.

## LIST OF REFERENCES


| Ref. | Author | Title | First Edition | Publishers |
|---|---|---|---|---|
| | | **Group 1 — General** | | |
| 1 | Greene | Elements of Hydraulic Power Generation | 1934 | Wiley |
| 2* | Barrows | Water Power Engineering (3rd Edition 1943) | 1927 | McGraw Hill |
| 3 | Gibson | Hydro Electric Engineering | | |
| | | Vol. 1. Civil and Mechanical | | |
| | | Vol. 2. Electrical | 1922 | Blackie |
| | | **Group 2 — Handbooks** | | |
| 4 | Davis | Handbook of Applied Hydraulics | 1942 | McGraw Hill |
| 5* | Creager and Justin | Hydro-electric Handbook | 1927 | Wiley |
| 6 | Ludin | Wasserkraft Anlagen | | |
| | | Handbibliotech fur Bauingenieure | 1934 | Springer |
| | | **Group 3 — Civil Engineering** | | |
| 7* | Schoklitsch | Hydraulic Structures (Volumes 1 and 2); translation in English by A.S.M.E. 1935 | 1929 | A.S.M.E. |
| 8 | Creager, Justin and Hinds | Engineering Construction of Dams | | |
| | | Vol. 1. General Design | | |
| | | Vol. 2. Concrete Dams | | |
| | | Vol. 3. Earth, rock-fill, steel and tumber dams | 1945 | McGraw Hill |
| | | **Group 4 — Mechanical Engineering** | | |
| 9 | Thomann | Die Wasserturbinen Vol. 1 | 1924 | Conrad Wittwer, Stuttgart |
| | | Vol. 2 | 1931 | |
| 10* | Tenot | Turbines Hydrauliques et Régulateurs Antomatiques de Vitesse Vol. 1 | 1930 | Librairie de l'enseignement technique, Paris |
| | | Vol. 2 | 1932 | |
| | | Vol. 3 | 1935 | |
| 11 | Kaplan and Lechner | Theorie und bau von Turbinen-schnellauffern | 1929 | Oldenbourg, Munich |
| 12 | Wislicenus | The Fluid Mechanics of Turbo-Machinery | 1947 | McGraw Hill |
| | | **Group 5 — Hydraulics** | | |
| 13* | Hunter Rouse | Fluid Mechanics for Hydraulic Engineers | 1938 | McGraw Hill |
| 14 | Bakhmeteff | Hydraulics of Open Channels | 1932 | McGraw Hill |
| 15 | Allen | Scale Models in Hydraulic Engineering | 1946 | Longmans |

# Scottish Hydro-Electric Scheme

## THE YEAR'S PROGRESS

THE North of Scotland Hydro-Electric Board's programme for the generation, transmission and distribution of electricity on which work is being carried out at present, has a total value of nearly £100 million states the 1948 annual report of the Board, which has just been published.

The first of the new hydro-electric schemes came into operation in December, 1948, one at Morar, Inverness-shire, and the other at Lochalsh, Ross-shire, and a further twelve hydro-electric stations with a total capacity of 423,000 kilowatts were already under construction by the end of 1948. Thirty-two turbines and twenty-six alternators for these stations are being built in Scotland. The Board's distribution system was providing electricity supplies to approximately 700,000 people at the end of the year.

Hydro-electric schemes, which were either being surveyed, promoted or constructed during 1948, will have an aggregate capacity of about 800,000 kilowatts, with an estimated annual output of about 2,200 million units, which is equivalent to over 50 *per cent.* of the present consumption of electricity in the whole of Scotland.

At the end of the year 6,759 workers were directly engaged on the construction of hydro-electric works and the erection of transmission and distribution lines. The Board is constructing a "Highland Grid" to interconnect the major generating stations, and part of this work will bring increased power supply to Aberdeen and Dundee areas.

As a result of the Electricity Act 1947 the Board, from 1st April, 1948, became responsible for generation, transmission and distribution in an area of approximately 21,600 square miles, which includes the cities of Aberdeen, Dundee and Perth, the towns of Inverness and Oban, the area of the Grampian Electricity Supply Company and the undertakings of a number of smaller local Authorities and Companies. It now operates (states the report) nine hydro-electric stations, six steam stations and thirty-two diesel stations, with a total capacity of 250,548 kilowatts. Units generated at these power stations during the calendar year, including the first three months when many of them were not under the Board's control, amounted to 741,357,476, of which water power produced almost 50 *per cent.* The Board exported to the British Electricity Authority's grid in Central Scotland 79,085,200 units during the period 1st April to 31st December, 1948.

***Our Parliamentary Correspondent writes:*** Orders have been laid before the House of Commons confirming two hydro-electric schemes for Perthshire which will produce when completed 88 million additional units of electricity a year at an estimated cost of £3½ million. The schemes, known as the Gaur and the Lawers projects, are the 15th and 18th in North of Scotland Hydro-Electric Board's plans.

The larger of the two schemes is the Lawers project which will meet the rapidly increasing needs of the Board's area and will supplement supplies of power for the Central Scottish Grid. The output will be 71 million units of electricity in an average year at an estimated cost of £2,850,000. The project covers a catchment area of 17½ square miles on the Ben Lawers range of hills in Perthshire. The scheme involves the enlargement of Lochan-na-Lairige and its use as a storage reservoir by building a dam 130 feet high near the present outlet of the loch. A series of aqueducts on the Ben Lawers range will divert into the loch the head waters of streams running from the south-eastern slopes of Ben Lawers into Loch Tay and from the north-western slopes into Glen Lyon. These aqueducts will be over 1,700 feet above sea level. The impounded water will have a usable fall between Lochan-na-Lairige and Loch Tay of 1,362 feet and it will be conducted by pipe-line and pressure tunnel to a generating station with an installed capacity of 30,000 kilowatts, to be built near Finlarig at the western end of Loch Tay.

The smaller Gaur project is planned as a simple and economic means of supplying urgently needed power to feed the transmission lines to Oban, Kinlochleven, Ballachulish, and Taynuilt, where there is a growing demand. A pipe-line will take the water to a generating station with an installed capacity of about 6,000 kilowatts. The scheme is planned to produce about 17 millions of units a year and it is estimated that it will cost £650,000.

The Fisheries Committee and the Tay District Salmon Fisheries Board were objectors to both schemes, but they withdrew their objections when the Board agreed to incorporate provisions for the protection of fisheries in the schemes. All other objections were withdrawn before the Orders were laid before Parliament.

## Sir Edward MacColl

The King's Birthday Honours List included the name of A. E. MacColl, the deputy chairman and chief executive officer of the North of Scotland Hydro-Electric Board, upon whom was conferred the honour of a Knighthood.

Sir Edward MacColl was born in Dumbarton in 1882 and educated at Dumbarton Academy, Glasgow Technical College, and Glasgow University. He served his apprenticeship with John Brown, Clydebank, and was on the staff of Glasgow Corporation Tramway Department 1902-1919. He was chief executive engineer and technical adviser of the Clyde Valley Electric Power Company from 1919-1927, during which time the first public electricity supply from a hydro-electric scheme in Scotland came into operation. From 1927-1943 he was manager for Scotland of the Central Electricity Board, supervising the erection of main transmission system in Scotland and the standardisation of frequency in the industrial West of Scotland. When the Hydro-Electric Board was formed in 1943, he was appointed deputy chairman and chief executive officer. Sir Edward MacColl is a member of the Institution of Electrical Engineers and a past chairman of the Scottish centre. He has about twenty patents to his credit for the control of high pressure transmission lines and electrical equipment, known as the MacColl Protective System.

# Scottish Projects Inspected

## VISITORS FROM OVERSEAS

ENGINEERS from Belgium, France, Sweden, Finland, Greece and Portugal have recently completed an extensive tour of hydro-electric schemes in the Highlands of Scotland, arranged for them by the British Council.

Visits to schemes at various stages of development and adapted to meet different needs and conditions were planned to demonstrate the great technical undertaking which will affect the whole economic life of Scotland and its people; and the itinerary took in some of the most impressive scenery in the Highlands —a very different setting from those which have characterized most important industrial enterprises.

Included in the tour were the Tummel-Garry hydro-electric scheme, Pitlochry, Inverness, the important schemes being developed at Glen Affric and Glen Moriston, the Glen Fannich workings, Strathpeffer, the Kyle of Lochalsh, the Fort William aluminium works, the Morar scheme, and Arrochar and the Loch Sloy and Loch Long schemes. Engineers on the sites conducted the party round, explaining the achievements and intentions of the project and answered questions.

Belgium.—Mr. Jules Bochart, Chief Engineer, Export Department, Ateliers de Constructions Electriques de Charleroi; Mr. Pierre Defays, Engineer for a Swiss firm in Belgium; Mr. Arsene Melignon, General Manager of the Societe Generale des Forces Hydro-Electriques du Katanga at Jadotoille, Belgian Congo (until the end of 1947); Mr. Frederic Simon, Chief Engineer of four syndicates created by the Belgian Colonial Ministry for studying the contruction of hydro-electric plants in the Belgian Congo.

Finland.—Mr. Veli M. Salenius, Engineer with Oy Stromberg Ab (design engineers).

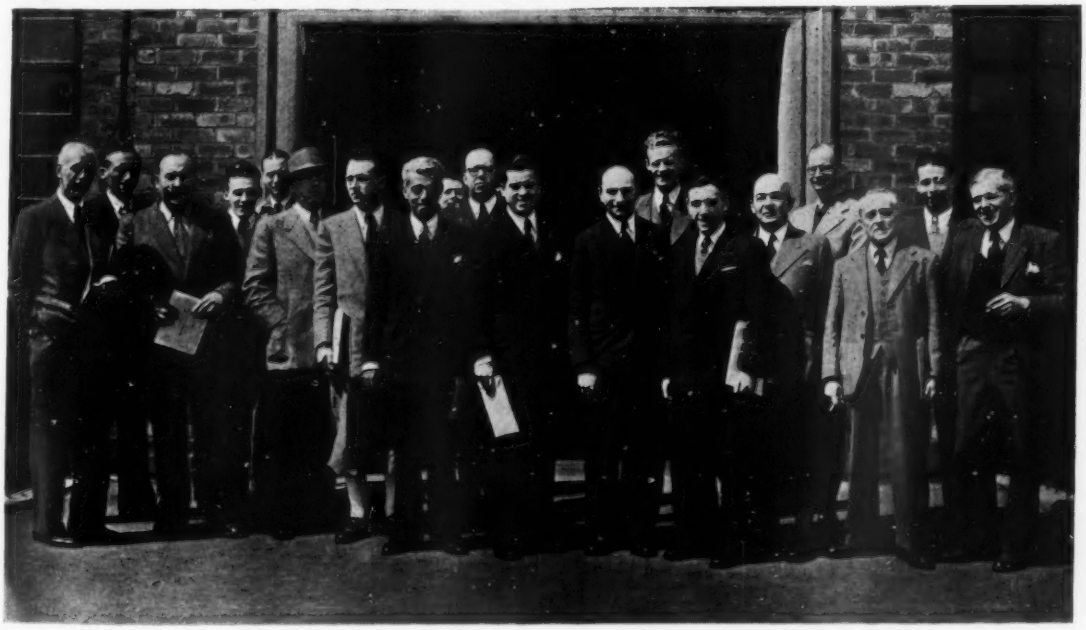
France. — Monsieur Andre Comte, Engineer (Assistant Manager) in Electricite de France, Service National (Direction de l'Equipement Hydro-Electrique —Region Alpes 11—Adjoint a la Direction des Travaux de l'Equipement Isere-Arc).

Greece.—Mr. John Fininis, Chief of Civil Engineering Department at the Athens Piraeus Electricity Co.; Mr. Theodore Papayanopoulos, Civil and Mining Engineer; Mr. Peter Vidalis, Electrical Engineer, Steers-Grove Company.

Spain.—Mr. Joseph Llovet-Charvet, Riegos y Puerza del Ebro SA (Ebro Irrigation and Power Company), the largest electricity supply undertaking in Spain.

Portugal.—Mr. Jose de Almeida Pereira, Hidro-Electrica do Zezere Co. In charge of erection planning, studies, and handling of the contract with the British Group formed by The English Electric Co. and Metropolitan Vickers, as contractors for the supply of electrical equipment for the Castelo do Bode Scheme.

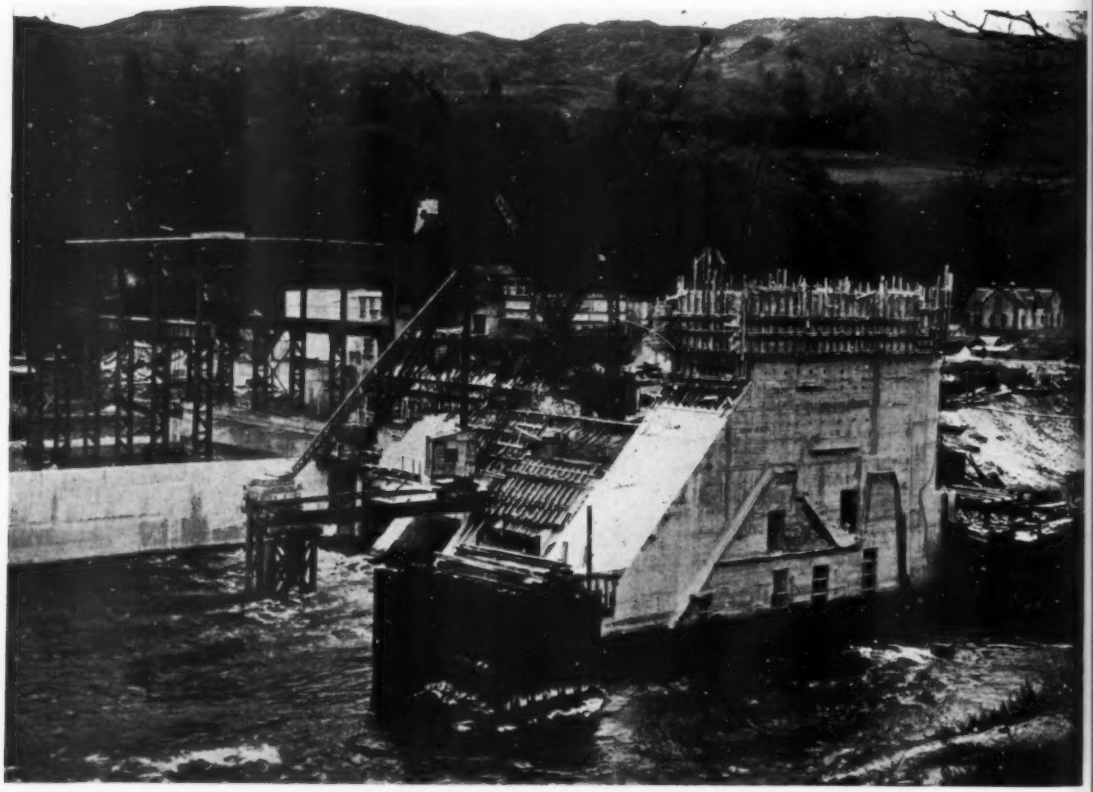
Sweden.—Mr. Nils Ivar Bjerström, Managing Director of Yngeredsfors Kraft Aktiebolag, Mölndal; Mr. Erik A. E. Blomqvist, Secretary of the Swedish Water Power Association and consulting engineer (Hydraulics); Mr. Ake J. G. Ericsson, Chief Engineer of the Hydro-Electric Department of AB Skandinaviska Elverk, belonging to the Swedish General Electric Company (ASEA); Mr. Anders Gudmar Helgesson, Engineer at Vattenbyggnadsbyran, Stockholm; Mr. Pär Johansson, Chief Engineer, P. Johansson Ingenjörsbyra.



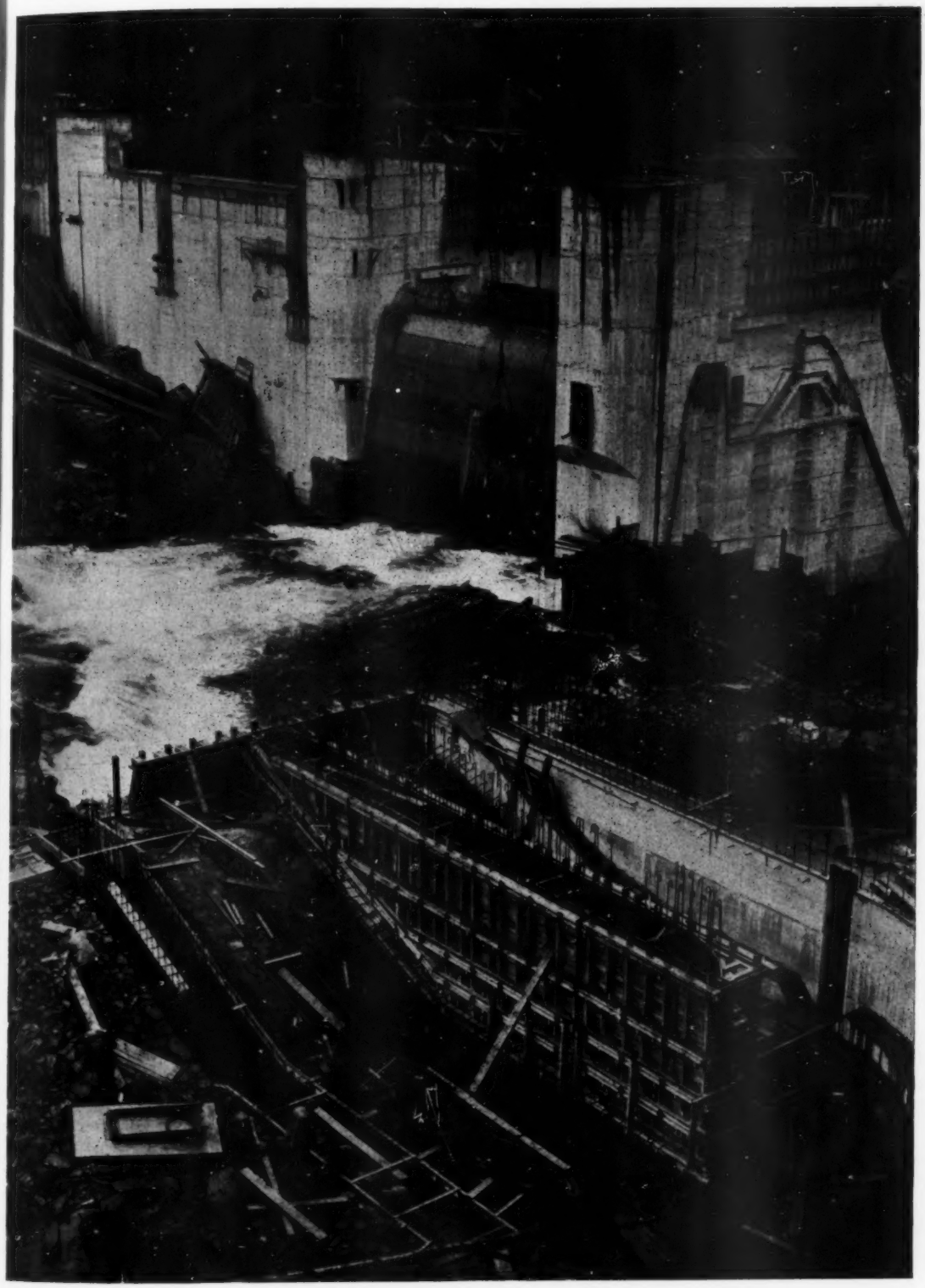
# Pictorial Progress Report

*The great hydro-electric project in the Highlands of Scotland is progressing well, and in this series of photographs we show the present stage of construction of some of the more advanced schemes. When the development plan is completed, at a total estimated cost of about £100 million, it is expected that its power output will satisfy nearly half of the present consumption of the whole of Scotland.*

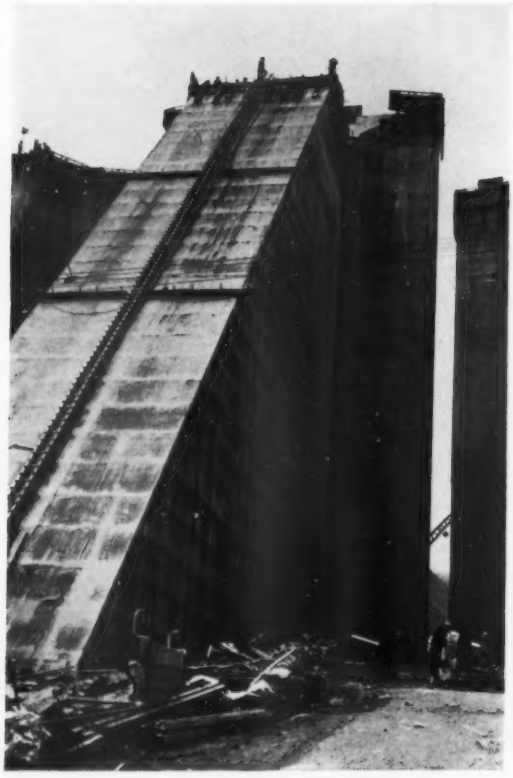
*Many of the illustrations refer to the stations at Pitlochry and Clunie in the Tummel-Garry Scheme of the North of Scotland Hydro-Electric Board. Ultimately; with a third power station at Errochty, this scheme will have a capacity of 145,000 kW, and an annual output of 300 million units. Other photographs show progress on the Sloy Scheme (comprising Lochs Sloy, Shira ana Alt-na-Lairige), which will have a plant capacity of 180,000 kW, delivering an annual output of 250 million units.*



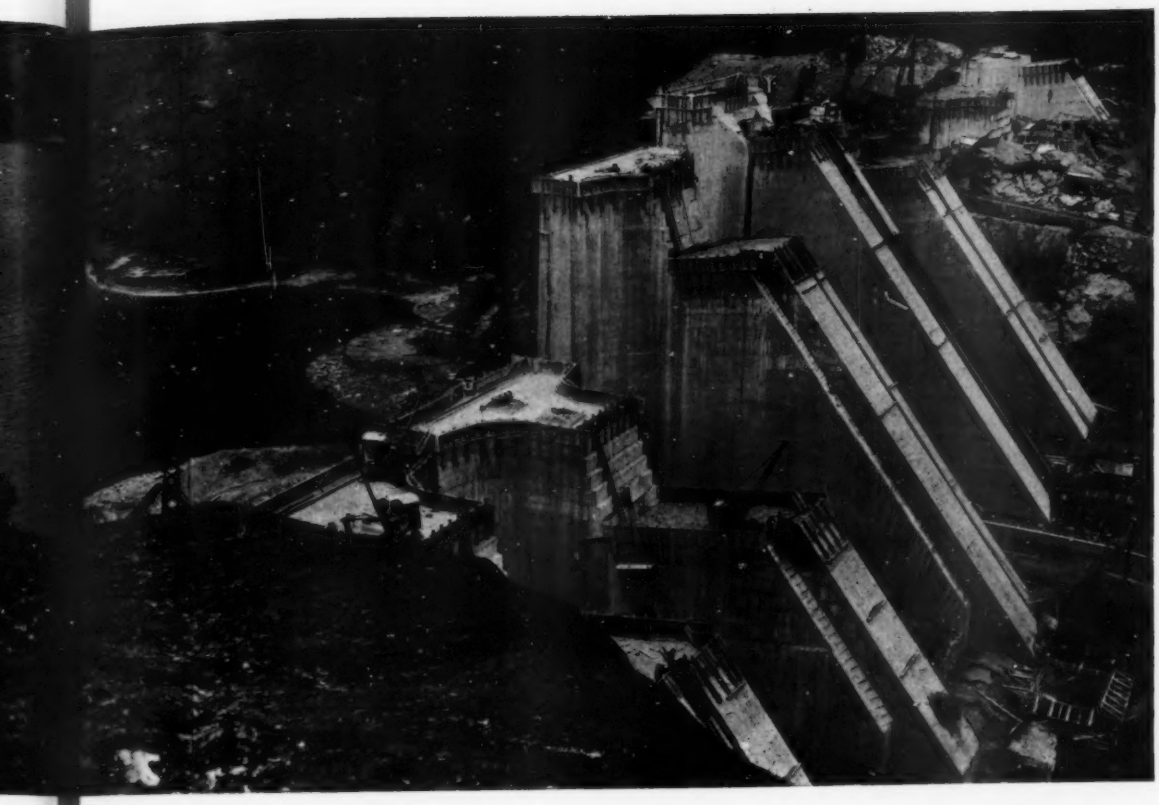
*The Pitlochry Dam: On the left is the framework of the power station forming part of the dam structure*

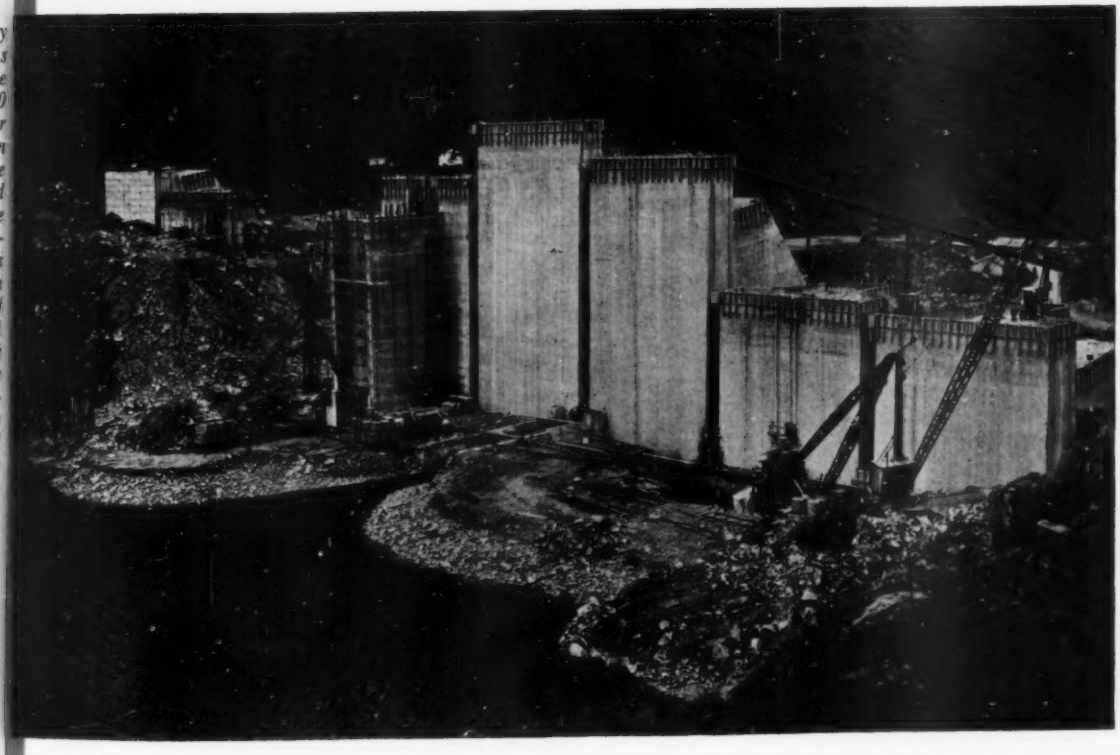


*Clunie Dam: The foreground shows the tunnel entrance which will pass the water to Pitlochry five miles away*

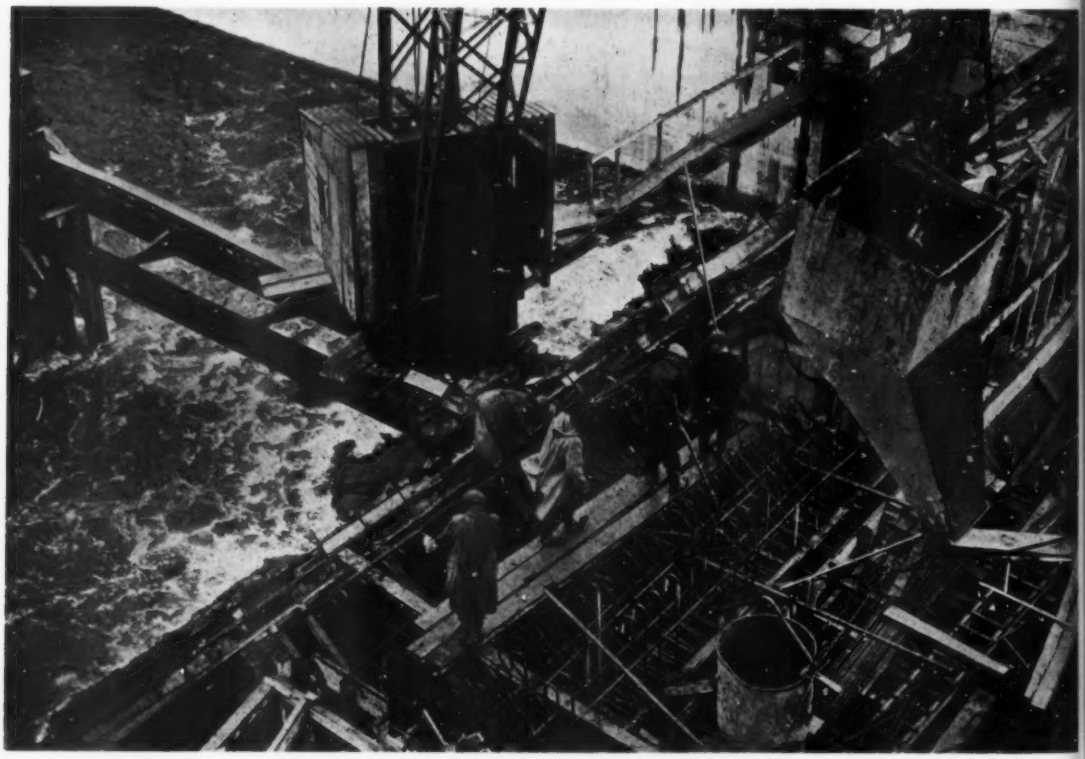


*A panorama of Loch Sloy showing the buttress formation of the dam. The reservoir will hold 1,200 million gallons of water collected directly from an area of six and a half square miles, and by diverted catchment from 26 square miles. Water will be conveyed by tunnel and pipes to the power station on Loch Lomond at the rate of 220,000 tons an hour. A close-up of one of the huge buttresses (top left). The power station on the picturesque shores of Loch Lomond (bottom left), and the upstream face of the Sloy Dam which will rise to 160 feet across the 1,200 feet wide valley (right).*

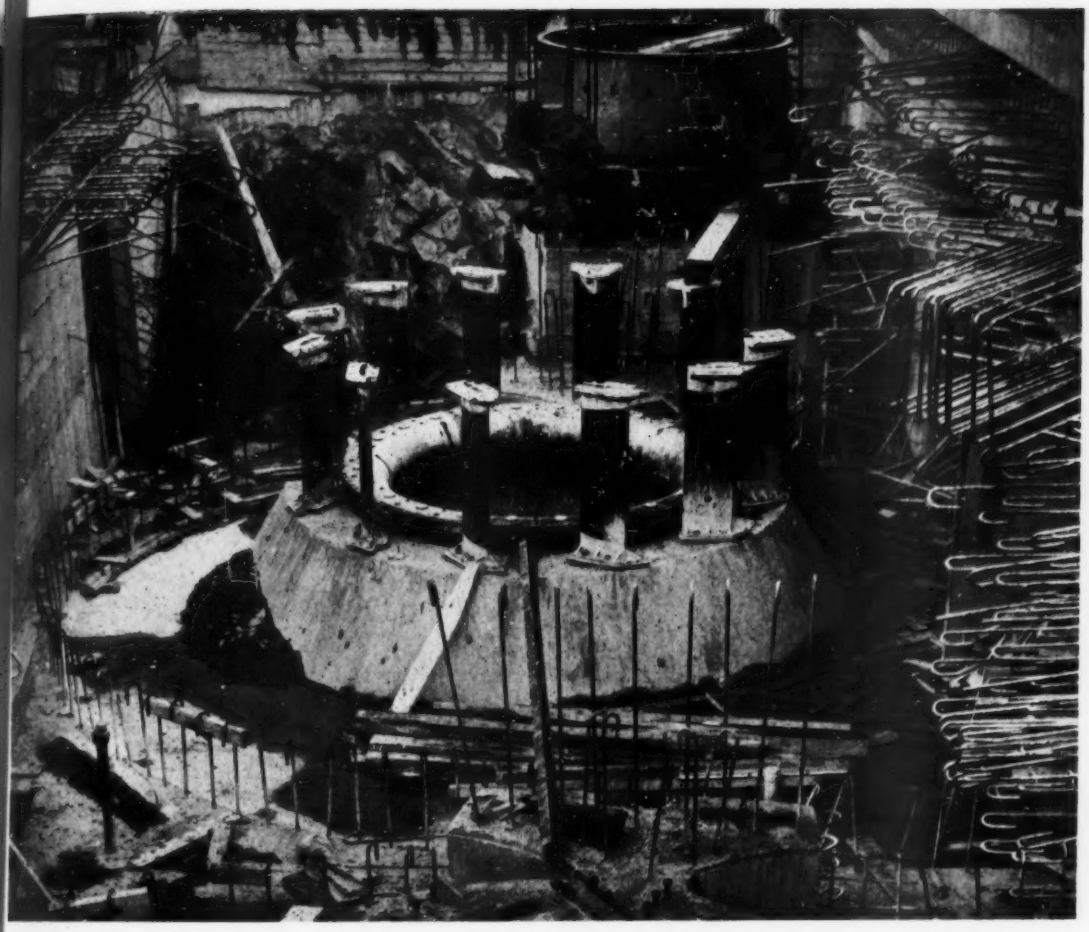




*Pipe lines to the Clunie power station—the water afterwards discharges into the reservoir at Pitlochry*



*Concrete workers on the huge wall of the Pitlochry Dam, with the swirling River Tummel below*



*Constructing the foundations for one of the turbines in the Pitlochry power station (above). Surveyors at work (right) near the Clunie intake. This tunnel, nearly two miles long with a finished diameter of 22 feet 6 ins., is the largest water tunnel in Britain*

# Power Development in North Canada

By E. W. HUMPHRYS (Northwest Territories Power Commission). A detailed description of one of the most isolated hydro-electric generating plants situated on the Snare River on the fringe of the Arctic Circle.

*Une description détaillée de l'une des stations génératrices hydro-électriques les plus isolées du Canada. Sur le fleuve Snare, en bordure du Cercle Artique, la construction en fut entreprise pour alimenter en courant de force à bon marché l'industrie minière du district de Yellowknife. Les conditions climatiques suscitèrent des difficultés particulières dans la préparation du site et dans la construction. Elles poseront de même, dans l'avenir, estime l'auteur, le problème délicat de l'entre tiendes lignes de transport du courant aux époques de gel et de débâcle; le ravitaillement du camp de la station sera difficile en hiver.*

*Se describe detalladamente una de las instalaciones generadoras hidroeléctricas más aisladas del Canadá. El proyecto está situado en el río Snare, bordeando el Círculo Artico, y fué desarrollado para proporcionar energía de costo bajo para la industria minera en el distrito de Yellowknife. La preparación del terreno y las obras de construcción ofrecieron dificultades especiales debido a las condiciones climáticas y el autor es de la opinión de que esto proporcionará los mayores problemas del porvenir para el mantenimiento de la línea de transmisión, caso de que se experimentaran dificultades durante los períodos de heladas y deshielos, y para atender al servicio del campo de la instalación durante los meses de invierno.*

ONE of the most isolated hydro-electric generating plants in Canada came into operation in October, 1948. This development is located on the Snare River on the fringe of the Arctic Circle, ninety miles north-west of Yellowknife, Northwest Territories. The plant was constructed by the Canadian Department of Mines and Resources and is operated by the Northwest Territories Power Commission, an agency of the department. The project was undertaken to provide low-cost power for the mining industry in the Yellowknife district. It will also supply additional power for the town of Yellowknife, the commercial centre of the area. The plant itself involved an investment of approximately $3 million, and the 115 kV transmission line and 33 kV step-down sub-station an mission line and 33 kV step-down sub-station required an additional $1,500,000.

On the basis of a continuous load at 50 *per cent.* of capacity, power is being sold at the Yellowknife terminal station at less than 2 cents per kWh, a high rate by most hydro-electric standards; but, due to the high cost of fuel oil in this area, this rate is less than half the cost of generation by Diesel engines.

Since very little run-off is obtained in the long winter season, it was necessary to provide ample water storage. This was done by the construction of a dam across the Snare River, one and a half miles below the outlet of Big Spruce Lake. The level of the lake has been raised by approximately 50 feet, to an elevation of 725 feet at full supply level, providing a maximum head of 62 feet and an average head of 56 feet, thus creating a reservoir of approximately 36 square miles in area. A spillway structure was constructed some three miles south-east of the main dam on an arm of Big Spruce Lake. The spillway sill was set at an elevation of 722 feet and, by the use of removable stop logs, the crest can be raised to maintain the full reservoir level at elevation 725 feet. Two short earth core retaining dams were constructed adjacent to the spillway in order that water might be retained up to full supply level. The natural topography of the region is such that several draws and lakes bordering the reservoir area provide emergency spillways should the run-off exceed the capacity of the spillway.

The main dam is 800 feet long by 73 feet high and 420 feet wide at its base. It is of the rolled clay core type with sand and gravel facing protected by a rock berm. The clay core was carried up to an elevation of 733 feet.

The dam was built over a small rock island in midstream. This natural feature facilitated the unwatering of the site for the dam foundations. A 16.5 foot square tunnel, 136 feet long, was driven through the island; this tunnel first carried the river flow during construction of the coffer dams and, subsequently, became the supply conduit for the main turbine. A second tunnel, 4 feet by 6 feet by 180 feet long, was driven parallel to the main unit to supply the emergency turbine generator unit.

The intake tower, a 70 foot high reinforced concrete structure topped by a gatehouse of insulated wood frame construction, was erected at the upstream end of the main tunnel. An electrically operated hoist is provided for raising and lowering the main gate while the gate on the smaller tunnel is operated by a hand chain block. Trash racks are installed ahead of both gates. The actual intake openings are 26 feet below the low water level which eliminates the possibility of ice formation in the intake area. The large body of water in the reservoir retains sufficient natural heat so that even with protracted temperatures of 50 to 60 degrees below zero, F., the ice cover on the reservoir is not expected to exceed a thickness of three feet or so. Tubular type five kW electrical heaters are installed in pipes embedded in the concrete structure

*Aerial views of the site of the Snare River Power Development, the picture above shows the specially constructed landing strip in foreground*

*The main dam, power-house and intake structure*

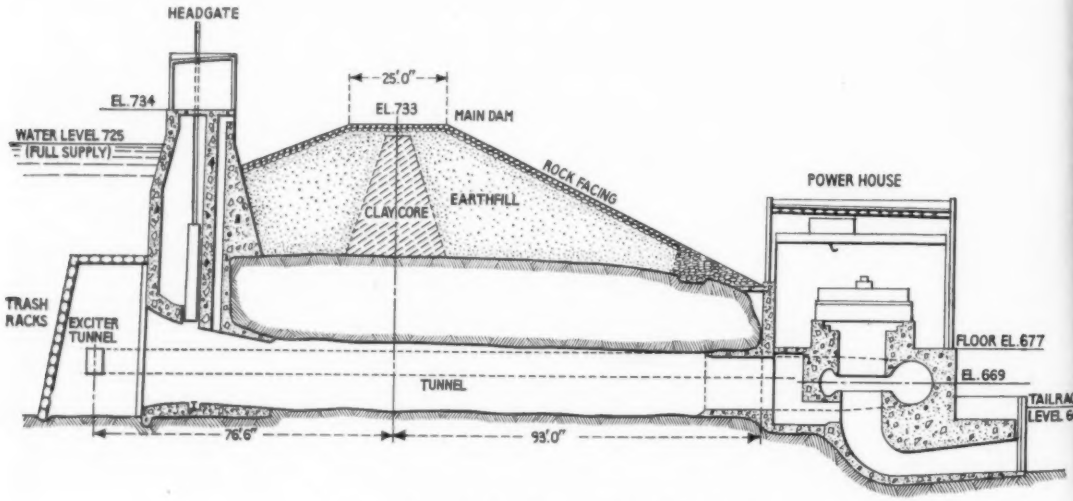
adjacent to the main gate guides to prevent ice formation at the water line. Two kW immersion heaters are also installed in the tunnel air vents and water level indicator well.

The powerhouse is located immediately below the dam and is built of concrete blocks, made on the site, with a structural steel framework and tar and gravel roof. The generating equipment consists of a single runner Francis type turbine with a single draft tube rated at 8,350 h.p. at a head of 56 feet, 128.5 r.p.m. driving a vertical alternator, delivering 7,000 kW (at 100 *per cent.* p.f.), at 60 cycles, 6,900 volts, 3-phase. The turbine is connected to the supply tunnel by a steel penstock, 13 feet 6 in in diameter and 40 feet long. Control is by a Woodward hydraulic governor capable of closing the balanced wicket type gates from full gate in $3\frac{1}{2}$ seconds, and sensitive to a speed variation of one quarter *per cent.*

A 90 kW, 250 volt exciter and permanent magnet generator are connected directly to the generator rotor. The alternator is fitted with water sprinkler pipes and a water-cooled hydraulic thrust bearing. Voltage regulation is provided by an amplidyne type regulator which can be used with either the main or spare exciter. This regulator is constantly regulating so that the voltage does not have to vary through a minimum before the regulator will act; and, by virtue of the absence of moving parts, other than the armature of the amplidyne generator which is driven at constant speed by an induction motor, the regulator has almost instantaneous response.

The emergency unit comprises a 900 r.p.m. twin runner horizontal turbine rated at 190 h.p. at a head of 52 feet, controlled by a butterfly valve and Woodward hydraulic governor. The turbine is coupled directly on one side to a 150 kVA, 550 volt, 3-phase, 60 cycle alternator with attached exciter and, on the other side to the spare exciter for the main generator.

The switch gear is of the cubicle type containing enclosed bus bars, removable oil circuit breakers, and hinged front panels carrying meters, control switches and protective relays. A swinging panel carrying voltmeters, synchroscope, synchronizing lights and



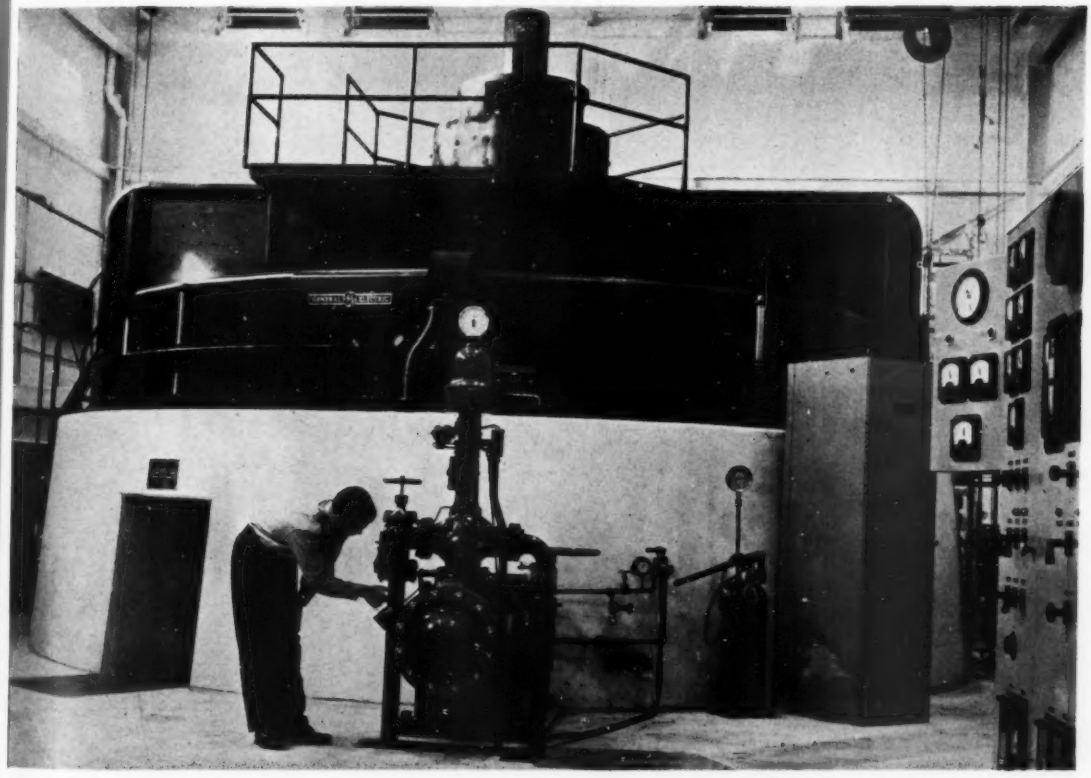

*Cross-section of the Snare River Development*

frequency meter is mounted at the left hand end of the structure.

The 6,900 volt supply is carried through the local service feeder to the outside camp area for distribution to staff buildings, warehouse, etc. A 300 kVA, 6,900/550 volt, 3 phase, oil-cooled transformer, located outside the power house and fed through the station service panel, provides 550 volt power for station service. Lighting and small motors, etc., are supplied by a 25 kVA, 550/230-115 volt air-cooled transformer.

The 150 kVA emergency unit may be paralleled with the main bus by closing its own circuit breaker, thereby connecting it to the 550 volt station service bus; opening the station service feeder circuit breaker will then place station service on the emergency unit only. Should the main unit be out of service the outside area can be supplied by the emergency unit feeding the 6,900 volt busbar through the 300 kVA station service transformer.

*Power-house, step-up transformers, and dam and water intake structure*



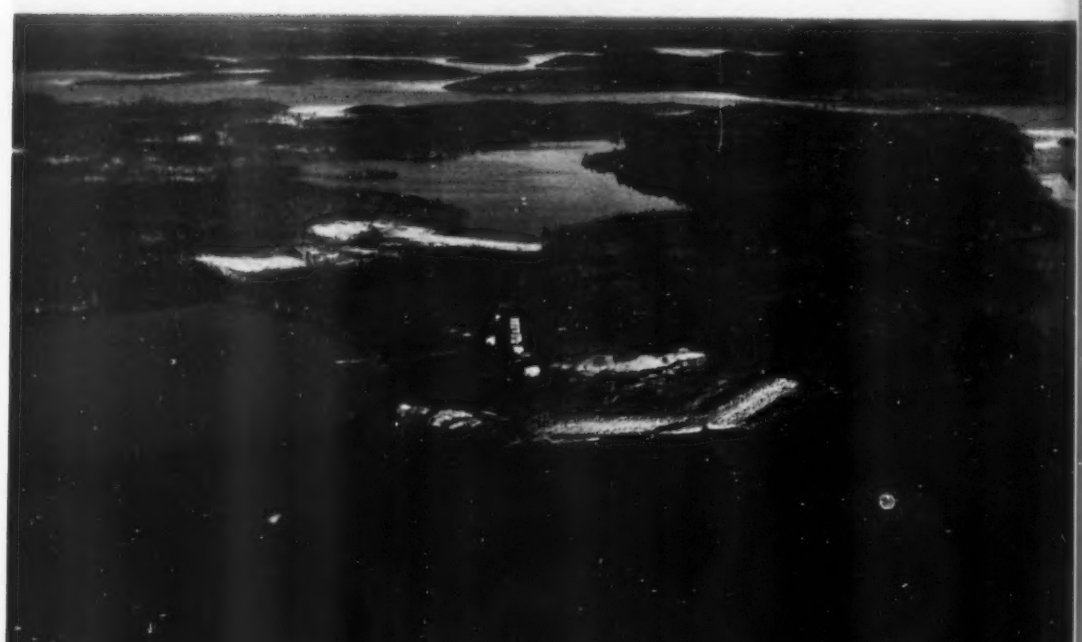
*Main generator, governor, lightning protection cubicle, and portion of switchboard*

*Above: Typical dead-end structure of transmission lines*

*Below: Aerial view of spillway, and containing dams. Construction camp can be seen approximately 3 miles S.E. of the main dam*

Instruments on the switchboard include a wattmeter, ammeter, reactive kVA meter, alternator winding and bearing temperature indicator, recording voltmeter, and recording wattmeter for the main unit. Integrating watt-hour meters are provided for the main transformer, station service and local service feeders. Duplicate switching and metering is furnished for the main and spare exciters.

The main generator protection consists of lightning arrestors and capacitors mounted in a cubicle adjacent to the machine, and phase differential and current differential relays are connected across the stator windings. The step-up transformer bank is protected by impedance relays on the low tension side and an over-current relay connected in the grounded neutral of the high tension side. The emergency generator, local service, and station service feeders have over-current relays, and a directional over-current relay prevents the emergency generator feeding more than two-thirds of its capacity towards the 6.9 kV busbar. An alarm bell operates on low



governor oil pressure and high winding or bearing temperatures in the main unit. Control voltage and emergency power house lighting are obtained from a 125 volt battery which also operates the circuit breaker closing mechanisms.

The main transformer bank is fed through an oil circuit breaker and consists of three 2,500 kVA, 6,900/66,000 volt oil-cooled transformers connected delta-star. Owing to the inaccessibility of the site and virtual impossibility of shipping a replacement transformer in the summer months, it was considered advisable to provide, with the initial installation, a fourth transformer as a spare. The neutral point of the star side is connected to a grid buried in the tail-race. The transformer bank is connected to the transmission line through an air break pole top switch. Lightning arrestors are connected on the load side of the switch.

The 90 mile transmission line is supported on wooden " H " frame structures with fir cross arms; conductor spacing is 11 feet. Since relatively few electrical storms are experienced in this area ground wire protection has not been provided. The majority of the poles are set in rock with a few on muskeg. Those set on muskeg are erected on a framework built of 30 foot poles, loaded with rock, and are guyed to wooden deadmen dug into adjacent earth. The ruling span is 650 feet, but the terrain is such that about 7 *per cent.* of the spans exceed 1,000 feet; the maximum span being 1,520 feet.

The transmission line terminates in a step-down sub-station consisting of three 2,500 kVA 66,000/33,000 volt transformers connected star-delta. Power is taken from the terminal station through 33,000 volt feeders protected by oil circuit breakers with over-load relays. Metering facilities are provided at this point.

**Maintenance Problems**

Communication between the power plant and the terminal station is provided by means of a two-wire telephone circuit, and a 5.1/7.6 kc carrier telephone system operating on the telephone circuit provides noise-free voice communication. The telephone drop of the carrier set at the terminal station is connected through a two-wire line to the telephone exchange in the town of Yellowknife thereby providing communication with any subscriber of the exchange. To guard against isolation of the plant through failure of the telephone circuit, two-way voice radio equipment is to be installed which will permit emergency communication with the Royal Canadian Corps of Signals' wireless station in Yellowknife.

To facilitate patrol and maintenance of the transmission line, nine cabins have been located along the line, eight to ten miles apart. Each cabin is stocked with emergency rations, fuel, tools, and essential line materials. A telephone located on a transmission line structure, adjacent to each cabin, enables the patrol man to communicate with either the plant or terminal station. The telephone is mounted in a weatherproof booth and is connected to the line through an isolating transformer, a current-operated relay and switches; a door-operated switch automatically disconnects the telephone set from the protector board when the door is closed so that it will not be needlessly exposed to damage from lightning.

The plant is serviced by aircraft operating on pontoons in summer and skis in the winter months of October to April. The patrol cabins are located adjacent to lakes of such size that a small aircraft can land and take off with safety. In the spring and autumn of each year there exists a period of three to six weeks during which ice conditions are such that neither pontoon nor ski-equipped aircraft can be used. To overcome this period of enforced isolation a 2,000 foot long air strip was constructed in the river valley below the power plant on which light aircraft operating on wheels from the Yellowknife airport can land. Transmission line maintenance in these periods would be extremely difficult, if not impossible, and it can only be hoped that if any major breaks occur, they will be confined to normal flying periods. However, the ice cover usually forms quite rapidly on the smaller lakes so that it will be possible to land on them long before the larger bodies of water have sufficient ice coverage to support even a light aircraft. Patrols in the winter months will also be carried out by track type vehicles.

**Weather Hazards**

The prolonged low temperatures experienced in the Northwest Territories dictated that an adequate heating system be provided for the power house and staff buildings. After careful consideration from the point of view of capital and operating costs, maintenance and efficiency, a steam heating system was specified. Steam is generated by a 200 kW electric boiler of the immersion element type operating at 550 volts, 3 phase. An oil-fired boiler with a petrol engine driven generator to operate the oil burner blower and condensate return pump was installed for emergency use, should all hydro power fail in the heating season. Steam is carried to the outside buildings by a steam main run in an insulated pipe box; heat loss from the steam main is sufficient to prevent freezing of the water and sewerage pipes which are also located in the box.

Probably the most difficult problem to overcome in the construction of this project was the transport of the construction equipment, building materials and plant machinery from Yellowknife to the site. A good deal of the equipment was too bulky to be carried by air except at great cost. The only alternative was to haul it over the frozen lakes during the winter months by caterpillar tractor trains. Each train consisted of several (usually five or six) sleighs and powered by a caterpillar-type tractor. A caboose attached to the end of the train served as sleeping and eating quarters. A good deal of equipment was taken by water transport from rail head to a point on Great Slave Lake, some 70 miles south of the plant site where " cat trains " were assembled. However, the greater part of the heavy plant machinery was not ready for shipment before the close of navigation in the autumn of 1947, and it had to be hauled by truck approximately 400 miles from rail head to a point on the south shore of Great Slave Lake. At this point tractor trains were organized and the material hauled over the lake and into the plant site, a distance of about 325 miles. Hauling on this lake is difficult and dangerous because of the wide cracks and pressure ridges in the ice. A " snowmobile " was used to pick out the route over the ice and contact with the trains was maintained by daily aircraft patrols. After nearly two weeks of continuous day and night travelling the trains arrived safely at the site, and although one tractor did go through the ice (it was salvaged later),

no material or equipment was lost. The bulk of the smaller material and supplies was taken to the job by a commercial air freight service operating Douglas DC-3 aircraft, which landed on the lake above the power plant in late winter months.

At the time of writing the plant and transmission line have been exposed to one season of low temperatures, and apart from minor troubles such as breaks in the telephone conductors, no serious operating problems have been encountered. It is expected that the main difficulties will be the maintenance of the transmission line, should trouble occur in the freeze-up or break-up periods, and that of servicing the plant camp in the winter months, due to problems associated with the operation of light aircraft in extremely cold weather.

# Progress in Ontario

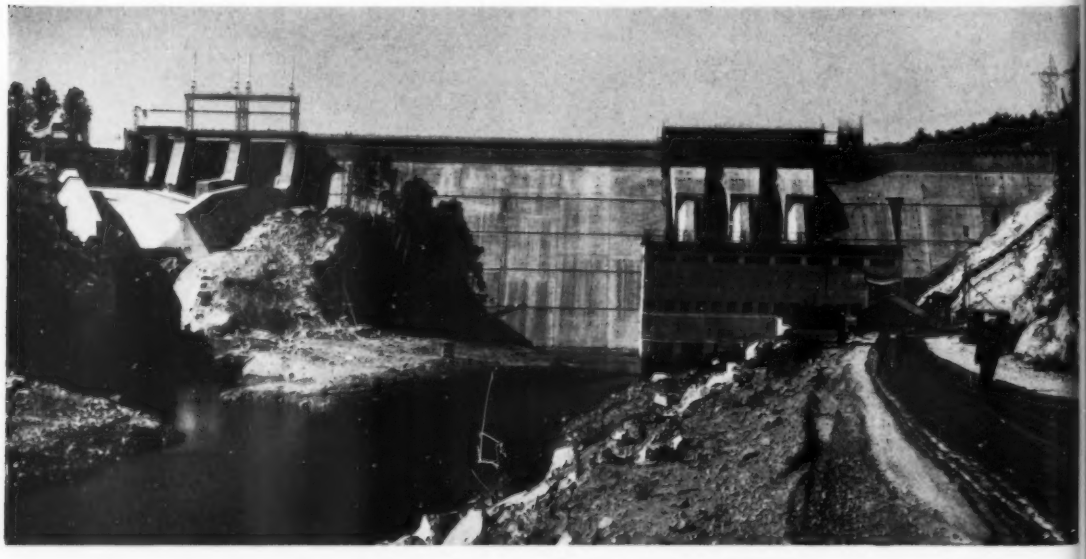
THE province of Ontario comes second in the amount of hydro-electric plant installed within its boundaries, in relation to the other provinces of Canada. Of the total of 11 million h.p. in commission by the end of 1948, after the 56 *per cent.* found in Quebec, Ontario has 26 *per cent.*

This is only natural when it is considered that Ontario also comes second in the estimates that have been made of the natural resources waiting development within the vast territories of Canada, as 18 *per cent.* of the ascertainable reserves of minerals come from the province. At the present time, some 28.5 *per cent.* of the mineral resources are being utilised and the hydro-electric developments, which are continually being planned, are directed towards increasing this figure.

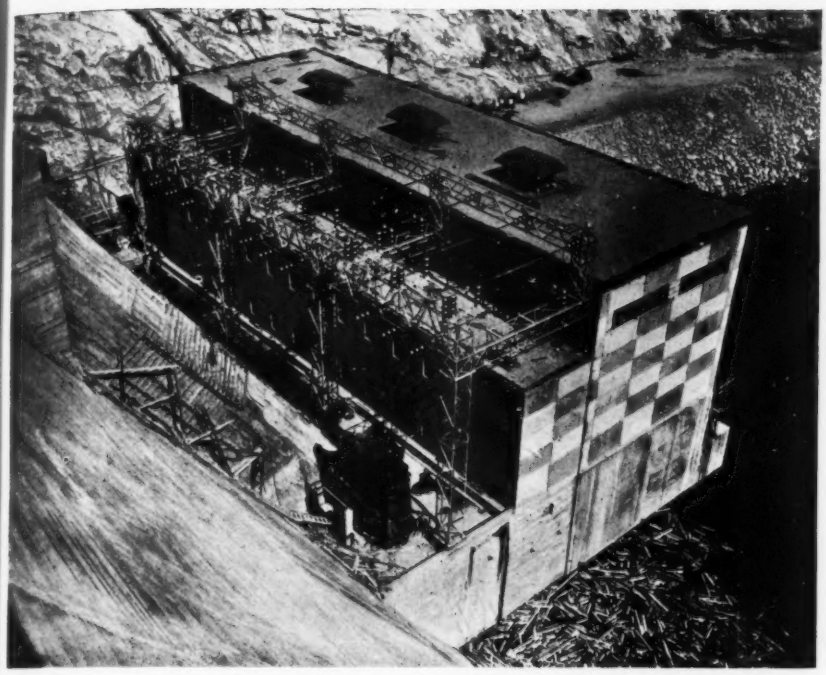
The pre-war average increase of hydro-electric power development in Canada was 300,000 h.p. a year, and in Ontario alone, the average annual increase has been, at least, in proportion to the general rate in the Dominion as a whole. The Ontario Hydro-Electric Power Commission's post-war programme has endeavoured to plan for the compressing of six years' normal construction work into about four years, in order to catch up with the power plant development needed but not installed during the war.

Among the recent projects which have contributed to the province's water power resources have been the Stewartville station on the Madawaska River, which was officially opened by the Prime Minister in September, 1948, when the first 20,000 kW generating set was put into commission. With a total capacity of 80,000 h.p. in three generating units, the Stewartville generating station has been erected in record time. Construction work started in the autumn of 1945, and the dam of 206 ft. in height bridges the 1,300 ft. gap between the cliffs on each side of the river. Civil work was almost completed in two and a half years. It involved the excavation of approximately 700,000 cubic yards of earth and rock, and the mixing and placing of 280,000 cubic yards of concrete. At one time during the peak period of construction, the continuous maximum pouring rate was 12,000 cubic yards of concrete. The total cost of the Stewartville development is estimated at $10,500,000.

Another plant, with an installed capacity of 53,000 h.p., was put into operation during 1948 at Terrace Bay on Lake Superior. Here the Aguasabon River was used to carry the waters of Long Lake into Lake

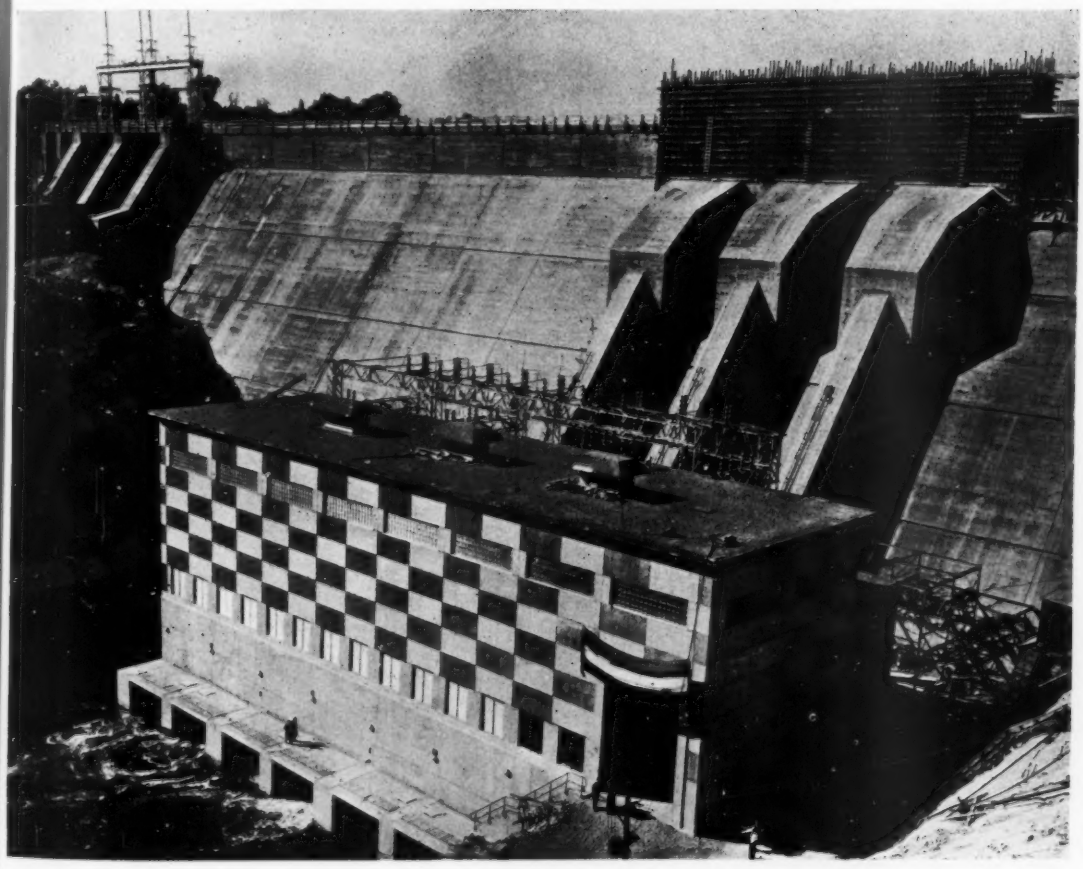


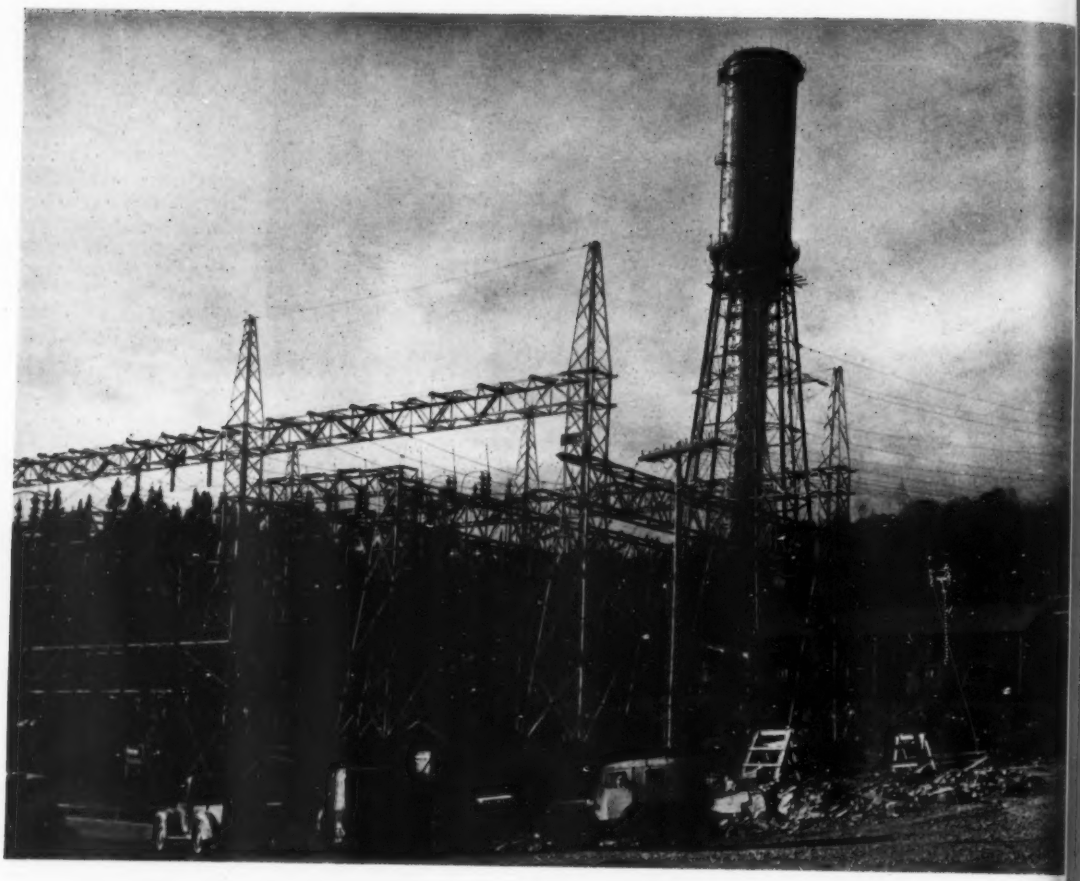
*Overall view of Stewartville dam and powerhouse*

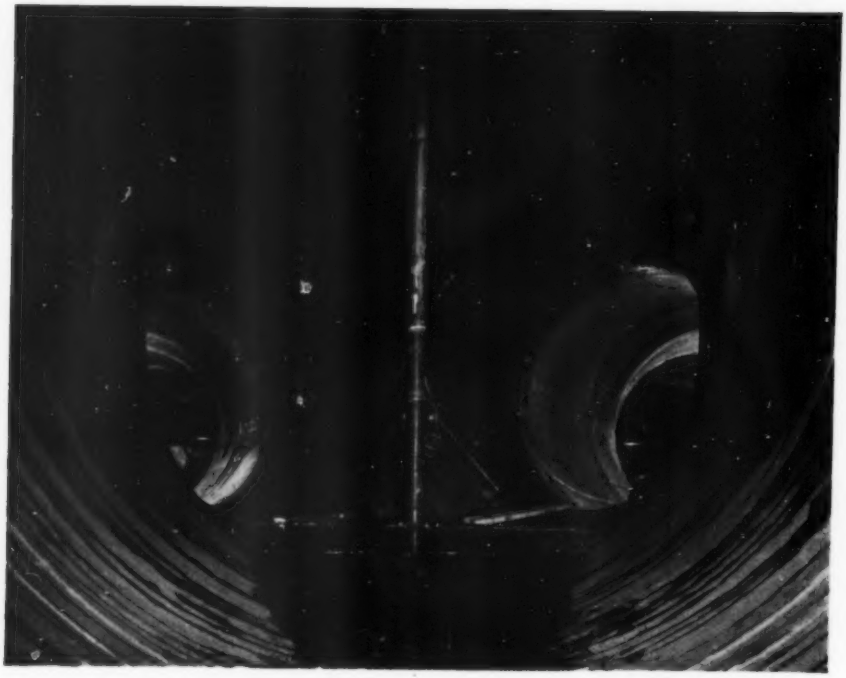


*Left: Looking down on Stewartville power-house from the top of the dam, showing the switching and bus structure. The transformer for No. 1 generating unit can be seen in the foreground. The development has a capacity of 60,000 kilowatts (80,000 h.p.)*

*Below: The main dam at Stewartville and the power-house viewed from the other side*







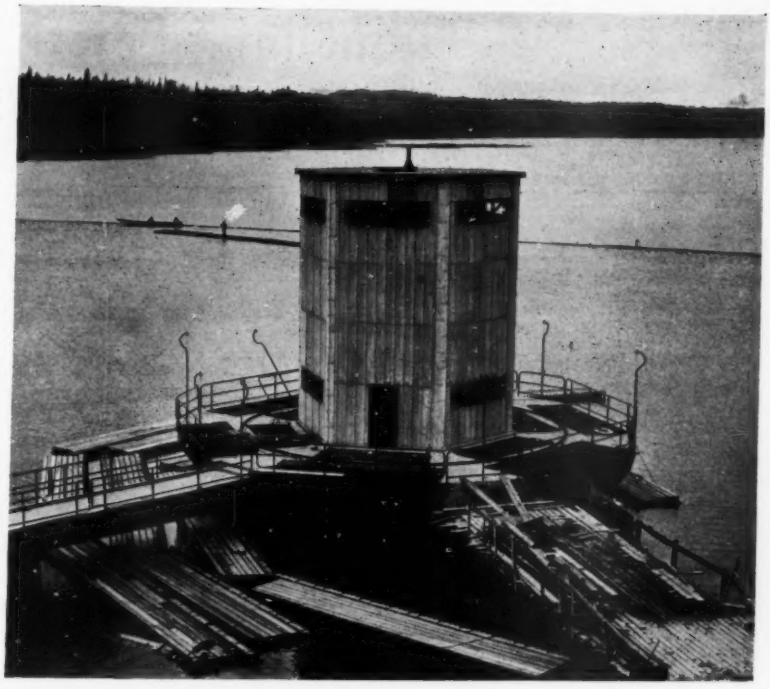
*Above: Aguasabon generating station showing surge tank and transformer area*

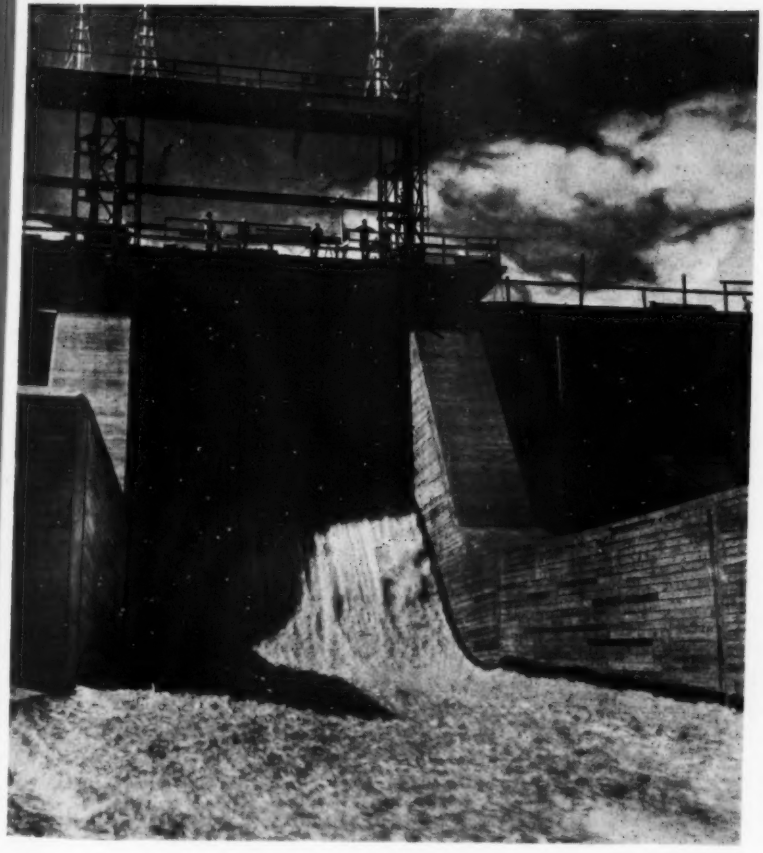
*Left: An intriguing view of the "Y" section that diverts the flow to the two turbines at Aguasabon power - house. The water flows from the intake through a 3,500 feet steel tunnel and 100 feet penstock to this junction*

Superior, passing through the power station on the way. The station is situated on the shores of the lake and was put into operation during October, 1948.

The main dam on the Aguasabon River itself is about 1½ miles above its outlet to the lake, and is 1,400 feet long, with a maximum height of 120 feet. It contains 85,000 cubic yards of concrete. A storage tank, 480 feet from the power house, is built on a 154 feet high steel tower, and is 32 feet in diameter, and 90 feet high. The height of the water in the storage tank above the tailrace is 240 feet.

Well to the North of these developments is the Ear Falls Station on the English River, where a 7,500 h.p. generating unit has recently been put into commission, bringing the total capacity to 25,000 h.p. This station first delivered power in 1930, and contains two 5,000 h.p. units, and another 7,500 h.p. generating set.





*Above: Intake at Aguasabon where the water enters radially from all sides through six ports controlled by a steel vertical cylinder gate and drops 270 feet down a concrete lined shaft bored through solid rock*

*Left: One of the two sluiceways at Stewartville. Controlled by 35 feet steel gates they discharge excess flows into a concrete - lined high - water channel*

**E.I.B.A. GOLF MATCH**

Score cards are available to golfers in the electrical industry for competition in the Electrical Industries National Golf Championship for 1949. The championship is organised for the benefit of the Electrical Industries Benevolent Association and is open to any male golfer who has a handicap of 24 or less on any course with a minimum length of 5,000 yards. The National Championship will be held at Moor Park in early October. Inquiries should be addressed either to the local E.I.B.A. Committee, or to Mr. A. H. Hughes, 21, Bloomsbury Street, London, W.C.1.

# Tunnelling Practice

A Civil Engineer reviews some of the problems of excavating in rock — it is a subject of particular interest because of the tendency to construct generating stations underground.

*Le problème du percement de tunnels dans le roc est d'un intérêt d'autant plus grand pour l'ingénieur hydro-électricien que l'on tend à construire des stations génératrices entièrement souterraines. Un ingénieur du génie civil étudie çi-dessous divers aspects du percement de tunnels, y compris le travail à l'explosif et l'excavation de vastes chambres où loger les groupes générateurs. Il décrit un certain nombre de bons exemples pratiques.*

*Los problemas generales relacionados con la excavación de túneles a través de rocas es de gran interés para los ingenieros encargados de obras hidroeléctricas, especialmente debido a la tendencia que existe de construir centrales generadoras enteramente subterráneas. En esta revista un ingeniero civil discute los diversos aspectos relacionados con la construcción de túneles, incluyendo trabajos de voladura y la excavación de grandes cámaras para alojar los equipos generadores de fuerza motriz. Se describe un buen número de ejemplos de trabajos muy bien planteados.*

THE general problem of tunnelling through rock is of great interest to the engineer responsible for hydro-electric work, especially in view of the tendency towards constructing generating stations completely underground. Outstanding examples of this practice are to be seen at Innertkirchen (Switzerland) and Krangede in Sweden.

The exit tunnels in these and other plants of a similar type vary in length from 1,200 to 3,000 feet, their lining depending upon the nature of the rock. But sometimes a water power scheme involves a considerable length of tunnel, a notable example being the 15 mile long concrete lined tunnel of the Lochaber scheme in Scotland. In this case tunnelling was carried out from some 20 faces simultaneously, total lengths of the adits being 6,360 feet and the combined depths of the shafts were 1,030 feet. Cross section of adits was 9 feet by 7 feet and of working shafts 18 feet by 12 feet.

In such work the strata through which the tunnel passes often show considerable variation; the author has had experience on hydro-electric construction work in Spain, where on one particular section of tunnel a large part of the mountain was a decomposed shale with the consistency of liquid mud. In this case the heading was close timbered with very heavy supports which were left permanently in place behind the concrete lining.

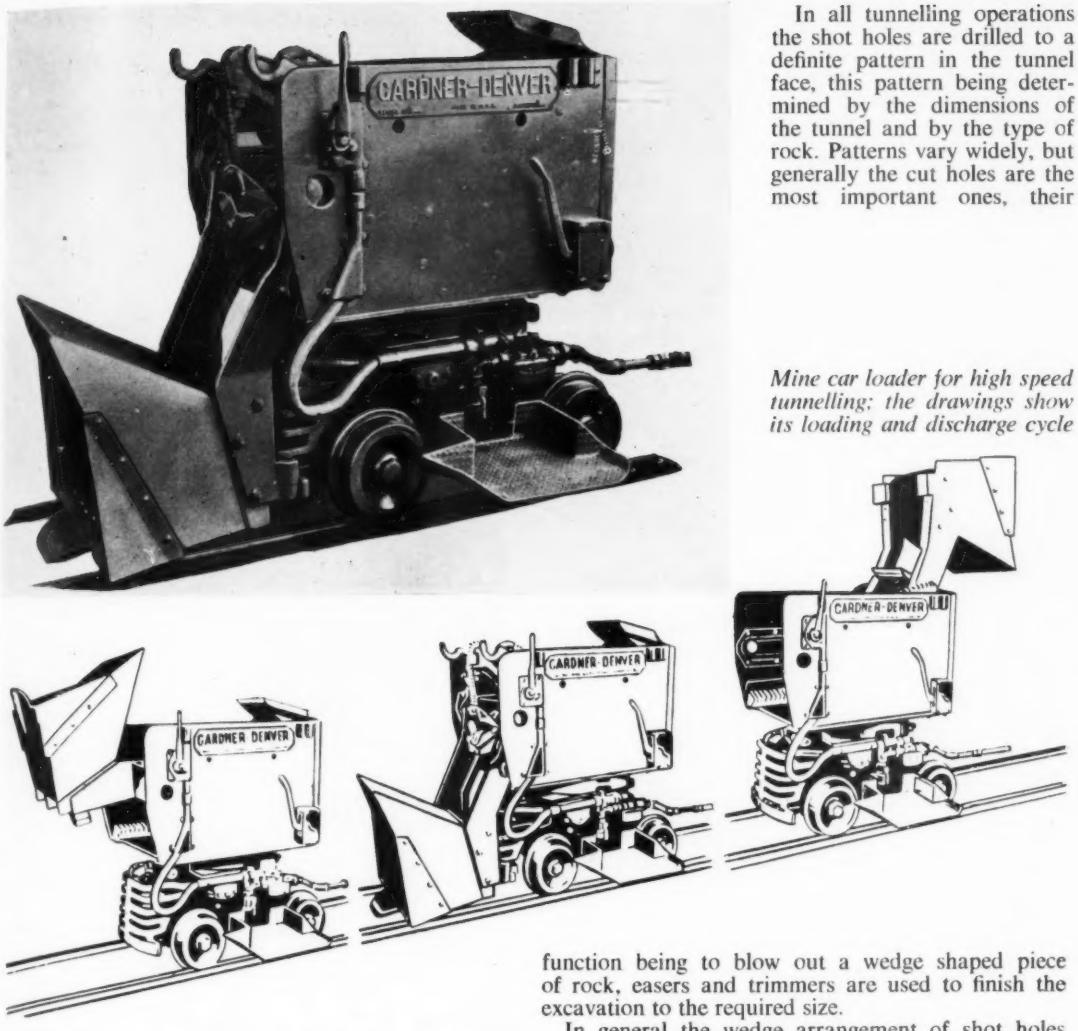
Tunnels are generally lined throughout their length with concrete in order to reduce skin friction to the lowest possible value. In order to obtain a smooth surface it is usual to employ collapsible steel shuttering, different shapes being used to conform to the periphery of the lining. The first section to be put in is generally the haunches on either side of the invert; these are concreted simultaneously, their tops being taken to about 3 feet above the invert. The sides of the lining then follow, the next process being concreting of the roof or ceiling, carried out by means of shuttering supported on travelling carriages. Finally, the invert (or floor) is laid and it is usual to employ *ciment fondu* for this purpose.

Where a large chamber for a power station has to be excavated deep in solid rock, this will involve shaft sinking on a large scale. In water bearing ground, cementation is generally carried out by pumping cement grout into holes from a plant on the surface. The shaft bottom may be cleared of water by means of air-operated pumps. The driving of tunnels at high speed through sound rock is mainly a problem of organisation and of correct application of mechanical plant. In recent years a very interesting type of high speed loader has been developed for removing the shattered rock from tunnels and headings, and this is shown in Figs. 1 and 2; the latter illustrates a complete loading cycle, from which it will be seen that the machine imitates mechanically the action of a miner using a shovel. It has many interesting mechanical features. The bucket automatically returns to the loading position under the action of gravity and the controls are very simple. Fig. 3 shows this loader at work in a narrow heading. A noteworthy feature of design is the pair of substantial rocker arms that roll on the frame of the machine; in this view the bucket is digging into the pile of shattered rock, which it will fling backwards into the skip just behind the operator.

Mechanical loaders of this type have greatly speeded up the pace at which rock tunnels can now be driven. Sir William Halcrow has stated in general terms that an average advance of between 70 and 100 feet a week may be expected on each working face in tunnels having a cross sectional area of 100 square feet; for smaller tunnels the corresponding advance may be 150 feet per week.

**Use of Explosives**

A very important factor in successful rock tunnelling is the correct use of explosives, which in modern practice may be classified as gelatines and dynamites. There is in addition a special safety type, known as Permitted Explosive, used where gas is present in the




*Mine car loader for high speed tunnelling; the drawings show its loading and discharge cycle*

rock, but this substance is generally employed only in coal mines. Gelignites and straight dynamites are classed according to nitro-glycerine content; for gelignite this is 62 *per cent.* and for Glasgow dynamite 60 *per cent.* Then there are the ammonium nitrate gelignites, in which the *percentage* of nitro-glycerine is designated by figure only, such as A.N.Gelignite 60, this figure representing the *percentage* of nitro-glycerine in the equivalent ordinary gelignite. Blasting gelatine should be employed in very hard ground.

Lorimer (*Some Uses of Explosives in Civil Engineering, by James Lorimer, B.Sc., Journal of Inst.C.E.—December, 1945)* has given some very useful hints concerning the application of explosives to tunnelling operations. He writes that a gelignite explosive of high density, of high to medium power, with good waterproof qualities and good oxygen balance, slightly plastic yet retaining rigidity during loading, is still the best type of explosive for this class of work. Polar Ammon-Gelignites are available in strengths ranging from 65 to 78 *per cent.*; Polar Blasting Gelatines have given satisfactory results all over the world and they remain the standard for tunnelling.

In all tunnelling operations the shot holes are drilled to a definite pattern in the tunnel face, this pattern being determined by the dimensions of the tunnel and by the type of rock. Patterns vary widely, but generally the cut holes are the most important ones, their function being to blow out a wedge shaped piece of rock, easers and trimmers are used to finish the excavation to the required size.

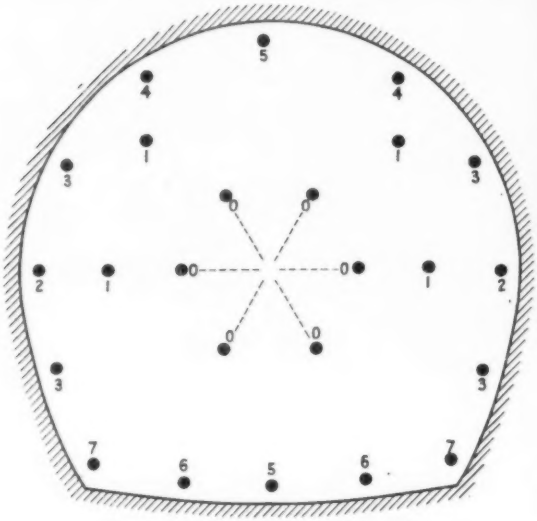
In general the wedge arrangement of shot holes gives the most efficient results, and it is the correct positioning of the cut holes which is the most important factor. Their position and direction are determined by experiment, and it is good practice to use a hole director, which takes the form of a large gauge and is used to direct the drills so that all holes are drilled at the desired angle. The author has found that in very hard breaking dolerite, for example, the best results were obtained by firing the cut holes first and blowing out a wedge shaped central portion, the easers and trimmers following later. Arrangement and charge of shot holes deserves and well repays careful study, for only thus can the best results be attained.

In tunnels of large cross section it is usual to mount the drills on large frames, or "jumbos," of the type shown in Fig. 4—this one was employed on the water power development in the Australian Alps. It has seven drills, and it will be seen that they can be easily arranged in any position and at any angle to suit the drilling programme.

This scheme—the Kiewa, to which reference was made in the last issue of *WATER POWER*—is being

carried out by the Victoria State Electricity Commission, and includes the driving of 18 miles of tunnels beneath the Alps in north-eastern Victoria. Tunnels range in size from 7 feet wide by 8 feet high to 16 feet by 20 feet; the largest tunnel is that for the tailrace, which will discharge water at the rate of nearly 34 million gallons an hour. The longest tunnel will be four miles.

With the exception of No. 3 power station, already constructed above ground, the five other stations will be located in large vaults excavated in the solid rock deep underground, thus following the trend of modern practice. The largest station is No. 2, with four generators having a total capacity of 98,000 kW; this will be located 650 feet underground. The generator room will be 220 feet long by 40 feet wide, and access will be gained by an electric lift. No. 4 station will be 450 feet underground, with a total capacity of 60,000 kW, to which access will also be by lift. Nos. 1 and 5 stations are so deep in the heart of the mountain




*Numbers denote order of firing*

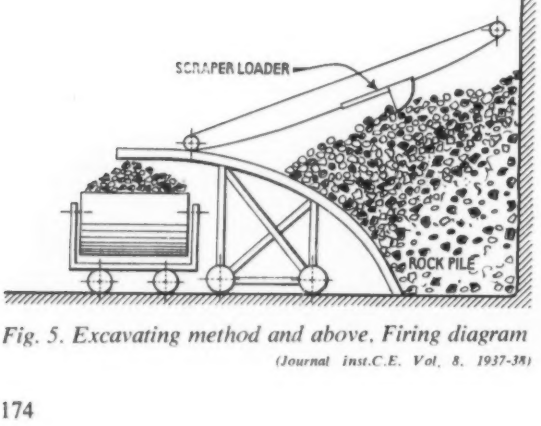
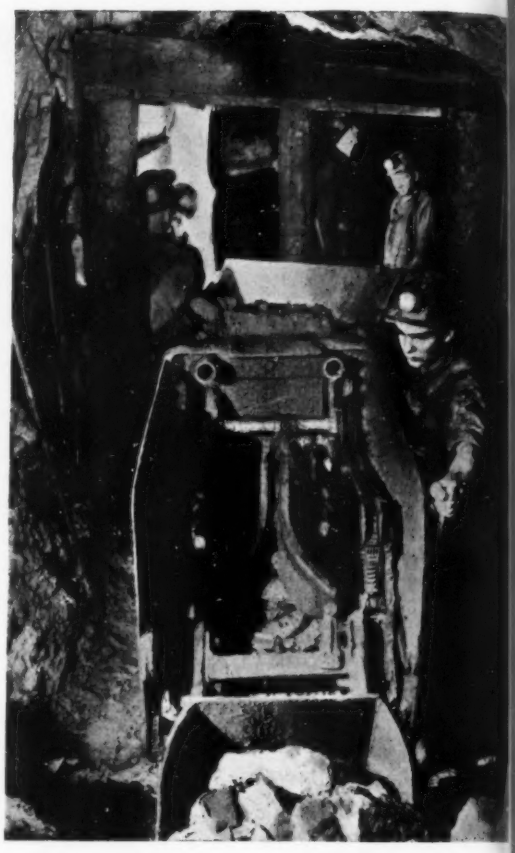



*Fig. 5. Excavating method and above, Firing diagram*

*(Journal inst.C.E. Vol. 8. 1937-38)*



*Rocker shovel at work in narrow mine heading*

that access will be gained through horizontal tunnels: the former will have a capacity of 60,000 kW and the latter of 32,000 kW, with three and two generators respectively. On this work the most highly mechanized equipment obtainable is being employed, and it is working three shifts for twenty-four hours a day.

The tasks involved in excavating large underground chambers will depend upon the nature of the ground; but the general method of opening up the chamber will be similar whether the rock be hard granite or soft shale.

After the access shaft has been sunk to the lowest point in the chamber a centre heading is driven for its full length; in the case of a large chamber it might be 10 feet wide and 8 feet high, and capable of taking two lines of track for removing spoil. From this centre heading side cuts are made at the centre and at the ends of the chamber, and a small heading should also be driven down each side. Then from the centre, and from the inner end, vertical shafts—or " raises "—are driven upwards, and the tunnel arch is opened from the top heading, which is also driven for the whole length of the chamber.

In hard rock the whole of the arch portion can be taken out for the full length of the chamber; the arch and side walls can then be built, and the rock remaining in the centre loosened with explosives and removed by mechanical shovel or scraper equipment. In loose or broken ground the arching will have to

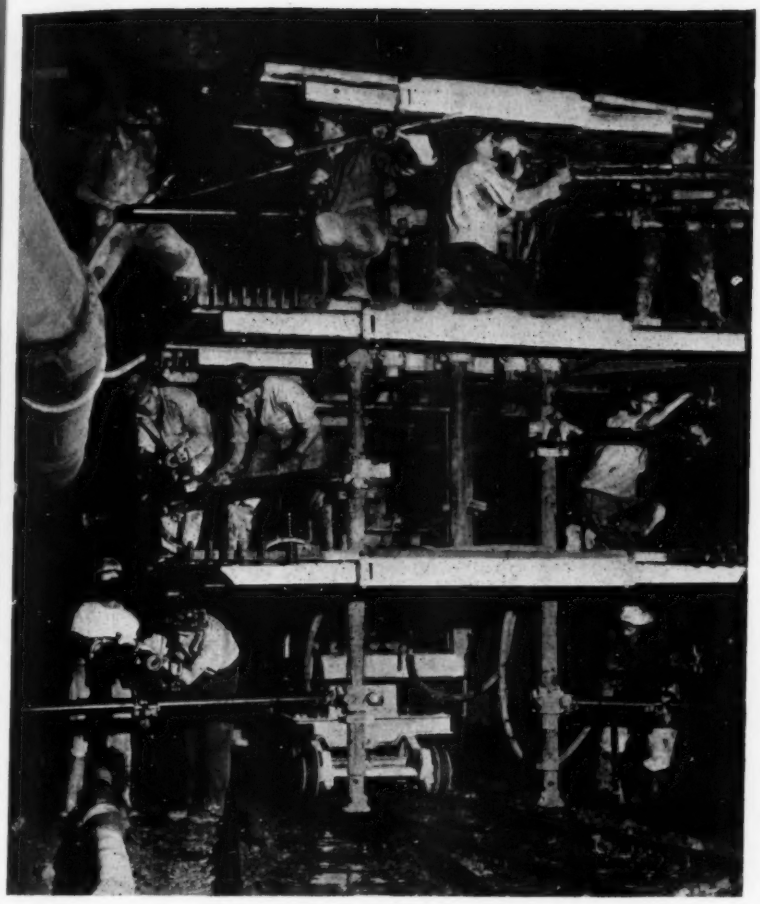


*Fig. 4. Seven-drill "jumbo" used on Australian water power development*

be taken out in short lengths, the arch and side walls being finished before passing on to the next length. This work is organised so that when the arch is being turned in the inbye length excavation is proceeding in the middle length, and so on until all the lining and arching has been completed. The centre "dumpling" is then removed by excavator. Such work often involves heavy timbering, the "bar and cill" method being used in soft ground.

Work will be greatly eased, especially in soft shale or similar ground, if steps are taken to drain away as much water as possible; but great care must be exercised to see that a "run" does not start in the ground; in certain cases this might extend to the surface, but that would only apply in very bad ground.

A sound example of tunnelling methods for a hydro-electric development is to be found in the Glenlee tunnel of the Galloway scheme. This tunnel has a total length of 18,988 feet and runs entirely through greywacke. Excavation was carried out from six faces, and a shaft at Craigshinnie was located with the object of dividing the length of the tunnel between the intake and the adit into two approximately equal sections, at the same time avoiding the use of an unduly deep shaft. After completion of the works, this shaft was used to bring additional water into the tunnel from two adjacent streams.

Drilling was done at each face by four drifter drills mounted on two columns, firing of the shot holes being carried out electrically using delayed action detonators and Nobel's No. 2 Polar Ammon gelignite. Average length of pull of a round was about 6 feet, and the average quantity of gelignite used for a cubic yard of rock excavated was 3½ lbs. During the earlier stages of the work the outer ring of holes was drilled well within the finished section of the tunnel excavation in order to avoid too much overbreak, for which the contractor does not get paid. Experience showed that although this method did reduce overbreak, a great deal of trimming had to be done and this is costly work.

Where necessary, rock support was provided by steel ribs formed to circular shape from 5 inch by 3 inch rolled steel joists at 5 feet centres in conjunction with heavy corrugated steel lagging backed by brickwork. These ribs and the brickwork were built into the permanent lining of the tunnel.

During the tunnel driving period electric battery locomotives were used to remove the excavated spoil, but after the main excavation had been completed, and thorough ventilation of the tunnel could be guaranteed, the engineers agreed to use diesel locomotives. The firing diagram shows the location of the shot holes, instantaneous shots being denoted by zero, the other numbers representing the number of seconds delay in each case; shots 1 can be termed easers, the remainder being trimmers. It is interesting to note that the 6 and 7 delays are the last to fire and these have the effect of throwing back the debris so that it can be the more easily handled by the scraper. The latter may be operated either by compressed air motor or by electric motor, and it is an ideal way of handling debris in such work.

The following table gives some idea of the progress of excavation of the Glenlee tunnel:—

| | |
|---|---|
| Explosives per round ... ... | 90 to 110 lbs., depending on quality of rock. |
| Best week's progress at one heading ... ... ... | 136 feet. |
| Average week's progress for whole tunnel ... ... ... | 100 feet per heading. |

One of the most interesting features of this work was the unusually long shuttering employed for the concrete lining. Figs. 5 and 6 are sketches of the excavation and concreting process respectively. The concreting gantry was made entirely of structural steel and was of the collapsible self-supporting type

comprising a single unit 150 feet long which permitted walls and crown to be poured in one continuous operation. The gantry was articulated so that it could negotiate the large radius bends in which the tunnel abounded.

The first step in carrying out the lining operations was to screed a narrow strip of the invert at the base of the wall on either side of the tunnel, after which the rails carrying the gantry were mounted on concrete pads and accurately set in their correct positions. The gantry was then run forward, accurately lined up, and the segmental steel panels which formed the shuttering were expanded by jacks until their lower edges nipped the strip at the base of the walls.

Contrary to the more general practice, the concrete materials were batched outside the tunnel and were transported to a mixer located at one end of the form, where, after mixing, the concrete was fed into special side tipping wagons. The latter were then hoisted on to the raised platform which ran the whole length of the form, and were pushed to the point where concrete was being deposited. The empty wagons were afterwards lowered at the far end of the gantry and were run back to the mixer along the tunnel floor. All placing of concrete was done by hand, and during the process the shuttering was vibrated by pneumatic hammers.

The best month's progress in placing the concrete lining was 2,250 feet, while the average for the whole tunnel was 1,300 feet a month. After completion of the concrete lining, holes were drilled through the crown of the tunnel at 10 feet centres and grout was injected at a maximum pressure of 50 lbs. per sq. in. The grout used had a water/cement ratio of 1 : 1; after completion of grouting total leakage into the tunnel did not exceed 0.06 cubic foot a second over the entire length of 19,000 feet.

A remarkable example of high-speed tunnel lining work was provided recently in the United States, when the Grossmont Tunnel of 6,292 feet length was lined with concrete to an inside diameter of 6 feet at the rate of 100 feet a day. This remarkable rate was made possible by the use of special pneumatic concrete-placing and form-moving equipment developed and manufactured by M. F. Kemper Construction Company. Collapsible steel forms in 20-foot sections were used and positioned by a car travelling on rails and powered by compressed air motors. An air hoist and roller chain, suspended from a beam projecting from the front end of the car, served to lift and carry the invert form, which was in a single piece; the arch form, made of five pieces hinged together, was collapsed and placed on the main frame of the traveller. Together, they were moved to the spot where they were to be set up and where steel reinforcing rings were already in position.

After the invert form had been lowered to the tunnel floor and the car run forward, the arch form was put in place by means of hydraulic jacks mounted on the car. Concrete was prepared in a batching and mixing plant set up at the intake portal of the tunnel; it handled a charge made up of 37 *per cent.* of sand, 30 *per cent.* of 1½ inch gravel, and 33 *per cent.* of 1 inch rock and pea gravel. To each cubic yard of aggregates was added six sacks of cement and 3½ ounces of Darex air-entraining agent. The batches were dumped into a hopper and fed by gravity to 1½ cubic yard pneumatic placers, made up in trains of three each, and hauled into the tunnel by a battery locomotive.

Upon reaching the position at which the concrete was to be poured the leading trailer of a train was connected to a discharge pipe of large diameter and to two smaller paralleling air lines by means of a switching device mounted on a rail car. Air was admitted to the unit by a lever-controlled needle valve, designed to disperse the air so as to ensure thorough mixing with the concrete. Pressures up to a maximum of 100 lbs. per sq. in. could be built up inside the chamber to deliver the contents into the forms at a speed ranging from half a minute to five minutes.

After each placer had discharged its load, it was backed up a few feet and a double-acting pneumatic cylinder caused a retractable set of rails to move out of the switching unit, forming a ramp over which the empty container is pushed on to a track surmounting the switching device. The retractable rails are then housed and the next placer hooked to the discharge pipe and air lines; after all three containers had been emptied they were hauled out by the locomotive and a full train run in.

We will now consider a few typical examples of tunnel driving in connection with hydro-electric works. In Great Britain the outstanding example is the 15-mile Lochaber tunnel (" *The Lochaber Water Power Scheme" by W. T. Halcrow, M.I.C.E.—Proc.Inst.C.E.—Vol. 231).* This tunnel has a mean diameter of 15 ft. 2 in. and is driven through a variety of strata. Various methods of driving were tried; a short top heading and a bench, a long top heading, extending from 100 to 200 feet in advance of the bench; and a long bottom heading extending 400 to 500 feet ahead, the top rock being afterwards shot down in several break-ups. The first method was generally adopted, with the heading 10 to 15 feet ahead of the bench. In a round of 26 holes in the

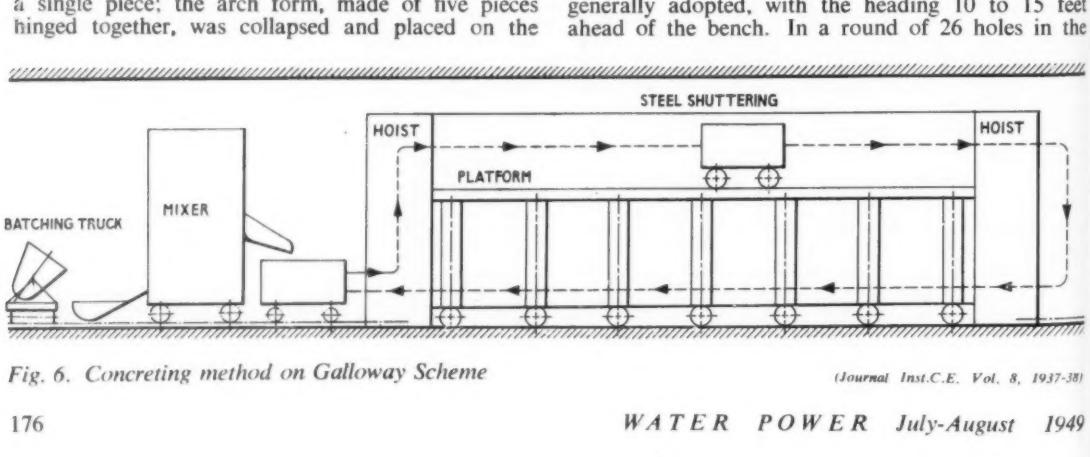



*Fig. 6. Concreting method on Galloway Scheme*

*(Journal Inst.C.E. Vol. 8, 1937-38)*

heading there were six cut holes, eight easers and twelve trimmers. The pull was 8 feet a round, and it varied from 4 feet in very hard hornfels to 10 feet in the softer rocks; the latter mainly consisted of Highland schists, the former of Eilde flags. The amount of gelignite used for each round averaged 180 lbs. for a pull of 8 feet; this is equivalent to 180 lbs. for 64 cubic yards of rock, or about 3 lbs. a cubic yard.

In the heading four pneumatic column drills were used; the drills in the bench being bolted to a horizontal bar. They were of the drifter type and consumed 100 cubic feet of free air a minute at a pressure of 80 lbs. to the sq. in. Compressed air was supplied for operating drills, forges, drill sharpeners, air hoists and pumps by 23 two-stage single-cylinder Sentinel compressors driven by electric motors; each had a capacity of 750 cubic feet of free air a minute at a pressure of 100 lbs. per sq. in. The supply pipes were 6 inches in diameter.

Rate of progress in the headings attained a maximum of 91 feet in one week, or 350 feet in four weeks; with all twenty-two faces fully organised, an advance of from 900 to 960 feet a week was achieved.

Another interesting excavation was that carried out in connection with the Tata Power Company's scheme in India. Here the main tunnel is 14,469 feet long and has a cross sectional area of 140 square feet; it has a slope of 1 in 255 and has been designed for a flow of 1,200 cubic feet a second, the maximum static head being 91 feet. It was driven from five shafts and two adits. The rock encountered was good Deccan trap and only about 10 *per cent.* of the tunnel had to be lined.

The most satisfactory tunnelling procedure was found to be a top heading 30 feet ahead of the bench, shot holes being 6 feet deep with a maximum depth of 7 feet. A bottom heading method was also attempted, involving the use of special stopers, as well as a top heading 100 feet ahead of the bench; both of these were abandoned. Heavy Leyner drills were used in the hard rock, but local labour achieved better results with smaller drills from which the water connection had been taken off. The quantity of gelignite used was between 8½ and 13 lbs. a foot of tunnel, equivalent to 1.7 to 2.6 lbs. per cubic yard respectively.

As a final example of hydro-electric tunnelling we shall take the Arapuni development in New Zealand. Although the length of the tunnel here was only 726 feet, the *percentage* overbreak was 15.7, due to the frequency of "slippery heads" and to the presence of loose joint planes in the rock. The consumption of explosives was only 0.48 lb. a cubic yard, which is not surprising in view of the nature of the ground. The author has referred to this work in order to show the wide variations encountered. Another interesting point is that the rock here is a pumiceous breccia with a porphyritic texture, and when excavated it produced so large a quantity of silt that there was much delay in clearing deep sumps.

In general, explosive consumption for granite and other hard igneous rocks will range from 6 to 8 lbs. a cubic yard; for hard shale and limestone from 5 to 7 lbs., and in soft stratified rock from 2 to 4 lbs., applied to a heading 8 feet by 7 feet.

In carrying out tunnel works nowadays the engineer has many scientific processes of great importance to help him, and he is fortunate in having available many alternative schemes for tackling soft or loose ground. Freezing has come very much to the fore in recent years, and by this means the pore water in ground can be frozen to give considerable mechanical strength. Both freezing and compressed air can be applied to any waterlogged ground, the former process being used at far greater depth.

# Men and Machines

## *Visit to B.T.H. Works*

ABOUT 150 members of the Institution of Mechanical Engineers (Midland branch) visited the Rugby works of the British Thomson-Houston Company recently.

The departments inspected included the turbine factory, gear factory, the transformer and generator factories, the new heavy plant building, fabrication factory, and the foundry. Several machines of importance were in various stages of manufacture. Among these were horizontal and vertical waterwheel alternators for hydro-electric projects in different parts of the world, including two 35,000 kVA, 500 r.p.m. horizontal machines for Abjora Power Station of the Vestfold Power Supply Company, Norway. These will be driven by double overhung Pelton wheels made by Boving & Co., the turbines being rated 37,000 b.h.p. Vertical waterwheel alternators were in course of construction for hydro-electric stations in India; including two 12,500 kVA, 214 r.p.m. machines for the Rasul power station, and a unit rated 7,250 kVA, 600 r.p.m. for the Papanasam power station, Madras. The last mentioned machine, which is arranged for closed circuit ventilation with multi-unit air coolers accommodated around the periphery of the stator frame, is a duplicate of three existing machines supplied in 1939. Although only in the early stages of manufacture, there were also three 62,400 kVA vertical waterwheel alternators for Spain. These are part of a large order received last year for hydro-electric plant comprising turbines, alternators, transformers, switchgear, and auxiliaries for the Los Peares Power Station of Fuerzas Electricas del Noroeste S.A. The three vertical alternators are each rated 62,400 kVA, 11 kV, 3-phase, 50 cycles, 0.85 power factor, 214 r.p.m., and will be driven by 72,800 b.h.p. Francis turbines which are being supplied by Boving & Co., as sub-contractors.

Several large transformers were seen in course of construction, including a 3,000 kVA, 66/33/11 kV unit for the Rasul project. In the new heavy plant building, which is nearing completion, visitors saw how waterwheel alternators having rotor weights up to 600 tons could be handled. The main bay of this building is 500 feet long and 90 feet wide and the height to the crane is 50 feet, the maximum weight that may be lifted being 200 tons. Members of the party were impressed by the expansion programme laid down for the fabrication factory which, when completed, will more than double its manufacturing area. Machine tools in the fabrication factory range from flame-cutting machines capable of cutting steel plate up to 24 inches thick, to hydraulic power-operated presses for cold forming bar material up to 2 inches by 7 inches (on edge).

# Mechanical Engineering Laboratory

## RESEARCH IN SCOTLAND

THE Department of Scientific and Industrial Research has announced plans for the establishment of a Mechanical Engineering Research Laboratory near Glasgow. Its object will be to assist industry in the more efficient use of engineering materials and improved methods of design. Of particular interest will be the research into hydraulic machinery, improved methods of measurements and the provision of basic data in advance of the immediate needs of the practising engineer. The Laboratory will also be a storehouse of information on scientific and research development throughout the world in the field of mechanical engineering, available for the use of industry.

Much of the research will be new to this country and some will be grouped in a new way. There is, for example, no hydraulic machinery laboratory in Great Britain which compares favourably with those in the U.S.A. and Switzerland. Some temporary accommodation has already been provided and work will start on lubrication and machining research.

The development and correct use of engineering materials is the most important factor in engineering progress and this has been taken into account in deciding priorities of research work and buildings. Unfortunately it is not possible to predict accurately what will happen to large components under fatigue conditions from research work done on a small scale. Special large testing machines are therefore being installed in the first permanent building to be erected.

**Hydraulic Machinery**

Industry needs help in solving the problems associated with the design of hydraulic equipment—turbines, pumps, and their associated parts such as valves and pipes. A hydraulic machinery building, with a flow capacity of 50 cusecs of water, will be an early priority. The water will be stored and used over and over again. A balance between basic and applied research will be struck. Basic work will include a study of the behaviour of incompressible frictionless fluids, the mechanism of boundary layer, flow, turbulence and fluid friction. Experiments, aided by calculations, will decide the economic roughness of surfaces. Reduced-scale models will be used for testing pumps and turbines using air, as well as water, as the working medium. The great advantage of air is that the equipment is much cheaper, and when the results are appropriately corrected the performance with water can be predicted. These and other researches will be done in the hydraulic machinery building, which will also be provided with apparatus for the accurate calibration of fluid flow meters.

Other buildings will be provided for experimental work on the mechanics of solids (stress and vibration), mechanisms and engineering metrology, mechanics of formation and machining. The basic nature of the research work has been emphasized because in the minds of many people engineering research involves work on complete units, which is far from being the case. Research carried out in several of the buildings may contribute to the development of any one piece of machinery.

Mechanical engineering research is also being done independently by industrial firms, by groups of firms in the form of the Research Associations, by universities and by other Government Departments; but there are still large and important fields which can only be tackled conveniently and economically by an establishment of the kind now being planned. There are also many basic problems which, once solved, will be useful to a number of quite different industries and which, therefore, are more appropriately tackled centrally.

The primary object of the D.S.I.R. and thus of the Mechanical Engineering Research Organization, is to serve industry. The new Laboratory, though located in Scotland, will fulfil a national need and will in time be one of the largest establishments devoted exclusively to industrial problems.

## JOHN AITON KAY

JOHN AITON KAY, Editor of the *Railway Gazette* and deputy chairman and managing director of the company owning the group of technical journals of which *WATER POWER* is one, died in London on July 8 in his 68th year. We make this announcement with the deepest regret and with a strong sense of personal loss.

Kay's interest in railways was intense and lifelong, but was far from exclusive. Energies such as his were not to be satisfied by a single production, and hence the succession of technical journals for which he and his associates were responsible. The policy laid down was that the basic industries should be covered and so there appeared in that order *Shipbuilding and Shipping Record, Colliery Engineering, Industrial Chemist, Building, Crown Colonist, Food, Wood, Diesel Railway Traction, Coke and Gas* and, within recent months, *Water Power*.

His was in the true sense a dedicated life. That interest in journalism which was to develop with such strength manifested itself early. While still a youth, he contributed articles on a number of subjects to journals of the period, and in 1898, soon after leaving Mill Hill School, he joined the editorial staff of the *Captain*. Twelve years afterwards, Kay visited America and succeeded in acquiring the *Railway Gazette* for British interests. Transport (1910) Limited was formed in this country and Kay became managing director and secretary, succeeding to the chairmanship in 1931. In 1945 control of the company was acquired by Odhams Press Limited and Kay became deputy-chairman, retaining the managing directorship.

His death removes from the scene a leading figure in the world of technical journalism, and a strong, forthright and kindly personality.

# Uganda's Resources

THE industrial possibilities of Uganda's hydro-electrification project — the harnessing of the Owen Falls—described in the March-April issue of *WATER POWER* are now under investigation by the Protectorate Government, following an extensive tour made by a technical mission of America's Tennessee Valley Authority undertakings.

Four experts—Dr. K. A. Davies, Mr. H. B. Stent, Dr. A. J. V. Underwood and Mr. C. R. Westlake—visited the T.V.A. towards the end of last year to study certain processes of manufacturing phosphate fertilisers which might be applicable in East Africa.

The aim of the Tennessee Valley Authority, under the Act of 1933, was to establish laboratories and experimental plants to produce fertilisers, as part of the scheme to rehabilitate eroded land, maintain soil fertility and prevent deterioration. This work resulted in several new processes which used the T.V.A.'s hydro-electric resources to prepare phosphate fertilisers from material available locally.

The object of the Uganda mission was to discover from the experience of the T.V.A. how best the rock phosphates in the neighbourhood of the Owen Falls could be processed. To this end its members focussed attention primarily on the chemical engineering research laboratories, and the fertiliser plants operated by the T.V.A. at Wilson Dam, Alabama, and on the fused phosphate plant at Godwin, Tennessee.

Discussions on the agricultural application of the new types of fertilisers with the Department of Agricultural Relations of T.V.A. at Knoxville, and with the United States Department of Agriculture near Washington yielded some useful information, while contact also was made with chemical engineering firms who have constructed plants for the manufacture of nitrogenous and phosphatic fertilisers.

Finally the problems to be solved in translating laboratory findings to the pilot stage and on to commercial production were thoroughly examined. It was found, for example, that the high temperatures required for many of them put a severe strain upon the refractories used in the plants, the smooth running of which was materially affected by the composition of the ores and impurities contained within them. The Uganda ore differs appreciably from those mined in the United States in that the chief impurities are iron minerals, the behaviour of which cannot be predicted.

They raise a problem of beneficiation (improving the quality of an ore by treatment — by fire, the addition of chemicals or other purifying agents) which requires a technique different from that used elsewhere. Even when this point has been solved it might still be the case that the iron content of the beneficial material is higher than that of the phosphate ores in general use in other parts. The effect of this additional iron content on manufacturing processes and on availability of the phosphate in the field would then have to be determined.

The Government of Uganda is putting new investigations in hand. They will be concerned with:—

The geology of the phosphate deposit;
Beneficiation processes;
Utilisation of by-products (for example the production of iron; possible large production of charcoal for use as a reducing agent in the manufacture of elemental phosphorous and iron metal); and
Obtaining supplies of sulphur or pyrites for the manufacture of sulphuric acid.

Emphasis is laid at the moment on establishing a phosphatic fertiliser industry; but the possibility of making nitrogenous fertilisers also is being considered.

## British Power Convention

THE first British Electrical Power Convention was held at Torquay in June. It took the place of the annual meeting of the Incorporated Municipal Electrical Association, and was sponsored by not only the British Electricity Authority and the North of Scotland Hydro-Electric Board, but also by other associations concerned with the manufacture, sales, and educational aspects of electrical engineering. Lord Citrine, chairman of the British Electricity Authority, presided and the principal guest at the convention was Mr. Attlee, the Prime Minister, who also spoke.

Among the papers of special interest to hydro-electric engineers was one by Mr. T. G. N. Haldane, president of the Institution of Electrical Engineers, on high voltage transmission in Great Britain; switchgear for systems of 200 kV and above was discussed by Mr. B. H. Leeson; power transformers for systems of 200 kV and over was the subject of a paper presented by Mr. H. S. Holbrooke; and high voltage research and development in British cable making industry was reviewed by Mr. T. R. Scott.

At the convention's exhibition the principal manufacturers demonstrated the lighter products of the electrical engineering industry; but photographic displays and models showed the progress in high tension circuit breakers, high voltage power cables, and other apparatus associated with large scale power transmission.

## A GOLD COAST SURVEY

The potentialities of the West African river Volta are to be investigated by a survey panel which will visit the area in October. A Colonial Office statement discloses that Sir William Halcrow and Partners have agreed to undertake the survey on behalf of the Gold Coast Government. Mr. Peter Scott, a representative of the firm, has had consultations with the Gold Coast Government, and he has already examined from the air over the Volta basin some of the problems involved. He considers there is "great potential power available, and that, with bauxite mines nearby, there is a ready use for all the power that can be generated." The coming survey will have particular reference to hydro-electric power at Ajena and/or Bui, and irrigation and drainage of lands in and near the Volta catchment area.

# Contractors' Notes

## Fifty Years of Electrical Engineering

JUBILEE celebrations of the **Metropolitan-Vickers Electrical Company** were held at Trafford Park Works, Manchester, in June—the exact anniversary date was July 10. The firm was founded as the British Westinghouse Electric & Manufacturing Co. Ltd., and commenced operations at Trafford Park, with the benefit of the experience of the Westinghouse Company of America.

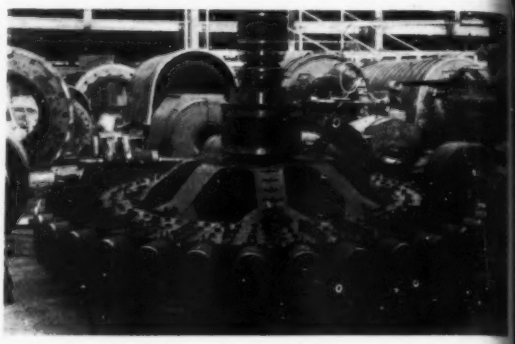
The company now operates several works in addition to those at Trafford Park; altogether employees number some 23,000 men and women, of whom nearly 19,500 are in Manchester. Heavy electrical plant, especially large turbo-alternators, has always been a special product of the Trafford Park Works,

*Stator of waterwheel generator for Pitlochry station*

which still have in use, though largely re-equipped, some of the big workshops that were originally provided with extraordinary foresight in 1899. Capacity is now available for building a million kilowatts of turbo-alternators a year. Except for the difference in design due to their respective speeds, this experience and plant is also available for the building of alternators for water power schemes and a number of such machines, for home and export markets, have been recently produced. Visitors at the jubilee celebrations were able to see, for instance, stators and rotors under construction for the Tainionkoski scheme in Finland, and machines for the North of Scotland Hydro-Electricity Board's Pitlochry station.

In switchgear and transformer production the shops are fully equipped to build equipment up to the largest sizes and highest voltages; air-blast switchgear of very high rupturing capacity was to be seen in various stages of manufacture and on test, as well as gear of other modern types. On the control side, the firm can offer remote supervisory equipment, control boards, instruments and protective devices to meet every possible requirement. Auxiliary equipment, including a.c. and d.c. motors and starters, low-voltage switchgear and so on, is also manufactured in great variety.

These notes will suffice to indicate that the company is able to handle complete electrical installations in every detail, but they mention only a few of the many departments shown to visitors on the occasion of the Jubilee celebrations. There is also, for instance, a fine



*The rotor belonging to unit on left*

research laboratory. Welfare arrangements are on most modern lines; the canteens serve 6,000 main meals daily, and there are social clubs of every description. Comprehensive training schemes, too, are in operation. Recent enterprises include work on gas turbines, electron microscopes, and the application of electronic equipment to an extraordinarily wide range of industrial problems. In executive direction it is of special interest to note that the company has always been run by men who entered its service in the most junior positions and have "worked their way up"; as a consequence it is claimed that the team spirit is particularly evident and that the firm is regarded as an institution in the best sense of the term.

**British Insulated Callender's Cables Limited.**—In the annual report, which has just been issued, reference is made to a new electronic type of surge counter developed in the company's research department and installed this year at the British Electricity Authority's research station at Leatherhead. The counter, which is operated from a suitable voltage divider or transformer connected to one phase of the transmission line, has the advantage of entirely automatic operation over long periods. Surges are divided into peak amplitudes of 2.5 times, 5 times, 7.5 times and 10 times the normal peak voltage of the line; the number of surges falling within these classifications are observed from counter readings. It is expected that surge counters of this type will prove invaluable in the compilation of accurate surge data on large interconnected transmission systems.

For the North of Scotland Hydro-Electric Board a new departure in transmission line survey technique was the use of aerial photography on a line over particularly difficult country.

Recent orders from oversea include 120 miles of double circuit 132 kV transmission line, with 122 miles of double circuit 66 kV and 99 miles of single circuit 66 kV lines for the Rasul hydro-electric project in the West Punjab (Pakistan). Lattice steel towers will be erected. The installation of 52 miles of double circuit 66 kV transmission lines for a hydro-electric project in Ceylon has commenced. In Portugal the construction of a 70 mile 150 kV transmission line between Zezere and Lisbon is proceeding.